This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

AIDS TO CHEMISTRY

PART II. INORGANIC
METALS

ARMAND SEMPLE

2/6

BAILLIÈRE, TINDALL & COX.

AIDS
TO
CHEMISTRY.

SPECIALLY DESIGNED FOR
STUDENTS PREPARING FOR EXAMINATIONS.

PART II.—INORGANIC (Double Part).

THE METALS,
QUANTIVALENCE, ELECTRICITY, TABLES OF ANALYSIS, ETC.

BY
C. E. ARMAND SEMPLE,
B.A., M.B., Cantab.; L.S.A., M.R.C.P., Lond.
EXAMINER IN ARTS AT THE APOTHECARIES' HALL,
PHYSICIAN NORTH EASTERN HOSPITAL FOR CHILDREN, HACKNEY,
PHYSICIAN TO THE ROYAL SOCIETY OF MUSICIANS,
LATE MEDICAL CLINICAL ASSISTANT AND SURGICAL REGISTRAR AT THE
LONDON HOSPITAL,
AUTHOR OF "TABLETS OF MATERIA MEDICA," "AIDS TO BOTANY," "AIDS
TO MATERIA MEDICA AND THERAPEUTICS (INORGANIC AND ORGANIC),"
"AIDS TO MEDICINE," ETC.

Fourth Thousand.

LONDON: BAILLIÈRE, TINDALL & COX,
KING WILLIAM STREET, STRAND.
DUBLIN: FANNIN & CO., GRAFTON STREET.
EDINBURGH: MACLACHLAN & STEWART, SOUTH BRIDGE.
GLASGOW: A. & W. STENHOUSE, COLLEGE GATE.
NEW YORK: PUTNAM & SONS.

1882.

193. g. 128d

BODLEIAN LIBRARY
9 MAY 33
OXFORD.

PREFACE.

THE contents of the following pages are simply intended as an introduction to an elaborate, and, I may say, an almost unlimited science. They are simply an abstract of lectures delivered to my pupils during the last ten years. Many of the metals, as Vanadium, Titanium, Tungsten, and others, have been purposely omitted, the endeavour having been, throughout the work, to embrace as many of the leading facts as possible, and to omit all details of apparently minor importance.

In preparing this, the second edition of Part II., I have deemed it expedient to add the following, viz.:

A brief description of Electricity and Electric Batteries, together with some rules and examples, with their solution, for determining the percentage composition and chemical formulæ of substances, with Tables of Analysis. This addition has been made since questions on these subjects are set and asked at the present day at most of the Examining Boards.

I am fully aware how infinitesimal is the amount of justice which it is possible to bestow upon the above matters in the few following pages, and I can only hope that the present volume may prove serviceable to the tyro upon the threshold of his study.

ARMAND SEMPLE.

8, TORRINGTON SQUARE, W.C.
February, 1882.

TABLE OF CONTENTS.

THE METALS.

Kalium.
Natrium.
Lithium.
Ammonium.
Cæsium.
Rubidium.

Calcium.
Strontium.
Barium.

ALUMINIUM.

Magnesium.
Zincum.
Cadmium.

Manganesium.
Ferrum.
Cobaltium.
Nickel.
Chromium.

Stannum.

Stibium.
Bismuthum.

Plumbum.

Cuprum.
Hydrargyrum.
Argentum.

Aurum.
Platinum.

Molecular Weight.
Specific Gravity of a Gas.
Formulæ of the Elements.
Atomicity or Quantivalence.
Variation of Quantivalence.
Basylous and Acidulous Radicals.
Acids.
Latent and Specific Heat.
The Air Pump.
Electricity.
Electrical Machines.
Electric Current. Electric Batteries.
Rules and Examples for the Determination of the Chemical Formulæ and Percentage Composition of Chemical Substances.
Tables of Analysis for the Commoner Metals and Acids.

AIDS TO CHEMISTRY.

THE METALS.

THERE are no less than 50 known metals, but inasmuch as some of these are found only in very small quantities, and their properties are but little ascertained, the most important only will be considered in the following pages.

All metals, except mercury, are solid at ordinary temperatures. They are good conductors of heat and electricity; many are susceptible of being polished, and of reflecting light; in the latter quality giving rise to the so-called metallic lustre. They are usually dense and heavy, ductile, malleable and tenacious; are all opaque, except in the very thinnest films, as with gold-leaf, through which light is capable of passage. They differ considerably from one another, both in chemical and physical properties; the lightest presenting the greatest affinity for oxygen; the heavier, the reverse.

If a solution of a metallic salt be decomposed by electrolysis, the metal will invariably be found at the negative pole, proving that metals are electro-positive. A salt is formed by the junction of a metal with a non-metallic element, and may be defined as the union of an electro-positive with an electro-negative.

If the name of the acid terminate in *ous*, as sulphurous, nitrous, etc., the resulting salt is termed an *ite*. If the acid terminate in *ic*, as sulphuric, nitric, etc., the salt then receives the name of *ate;* either being *sub—mono—sesqui—di—tri—tetra*—sulphite or sulphate, according to circumstances.

Those substances termed *Haloid salts* have already been described under Halogens.

The monads chlorine, bromine, iodine, fluorine, form, with *one* atom of hydrogen, *normal acids*, viz., HCl, HBr, HI, HF; and with an atom of any basylous radical,* ordinary *normal salts*, viz., $NaCl$ (chloride of sodium or common salt), KBr (bromide of potassium), KI (iodide of potassium), etc. Dyad radicals, as sulphur, selenium, etc., since they form with *two* atoms of hydrogen *normal acids*, viz., $\left.\begin{matrix}H\\H\end{matrix}\right\}SO_4$ (sulphuric acid), and with two atoms of monad metals, *normal salts*, as $\left.\begin{matrix}K\\K\end{matrix}\right\}SO_4$, (sulphate of potash) will clearly give rise to intermediate bodies consisting of one atom of hydrogen and one of metal, viz., $\left.\begin{matrix}K\\H\end{matrix}\right\}SO_4$. These are termed *acid salts*, being neither normal acids nor normal salts: they do not always redden litmus, and in a few cases have even an alkaline reaction.

An acid is a compound body, having usually a sharp, sour taste, and its solutions reddening litmus. It always contains hydrogen, and this can be replaced by a *basylous radical*,* or metal, thus giving rise to a salt.

The quantivalence or atomicity of a metal is determined by its combination with the monad chlorine; but it is frequently found that more than one compound is formed, as with tin, where we have $SnCl_2$ (stannous chloride), and $SnCl_4$ (stannic chloride). We have no *positive* means of determining whether this metal is a dyad or tetrad, but it is customary to consider the compound which contains the more chlorine as indicating its atomicity. Those salts containing the lesser amount of acid are termed *ous;* those containing the greater amount *ic*, viz., stannous and stannic chlorides, ferrous and ferric sulphates. (See pp. 52, 62).

It is convenient to consider the metals in groups, and thus we commence with

GROUP I.—THE METALS OF THE ALKALIES.

POTASSIUM (K)	LITHIUM (Li)	CÆSIUM (Cs)
SODIUM (Na)	AMMONIUM (NH_4) hypothetical	RUBIDIUM (Rb)

POTASSIUM—KALIUM (Kali, ashes).

Symbol, K. Combining weight, 39. Specific gravity, 0·865.

Description.—A bluish-white, lustrous, soft metal, very rapidly tarnishing in air from the formation of a film of oxide.

---

* Any substance playing the part of a base, as methyl (CH_3), ethyl (C_2H_5), etc.

When thrown upon water (hot or cold) it instantly takes fire, liberating hydrogen (potassiuretted*) and burning with a *violet* flame. This substance combines with many non-metals, as chlorine and sulphur, evolving light and heat.

Preparation.—(1). Potassium was discovered by Sir Humphry Davy, who, by electric action, decomposed caustic potash (KHO) into potassium, hydrogen, and oxygen. Until this experiment was performed, KHO was considered an elementary substance.

(2) By heating potassium monoxide (K_2O) to a high temperature in an iron retort with charcoal (C). Thus—

$$K_2O + C = CO + 2K.$$

Carbonic oxide is formed, which escapes as a gas, and potassium, which is volatile at a red-heat, distils over, and is collected under rock-oil or naphtha (these substances containing no oxygen). A second distillation is requisite, since a black explosive compound is formed in the first preparation.

Sources of the Potassium Compounds.—The felspar of the granitic rocks contains from 2 to 3 per cent. of potassium, but this source is not generally available.

Plants are capable of slowly assimilating potash from rocks and soils, and by burning these plants and extracting the ashes with water, a soluble potassium salt is obtained. This is the "crude potassium carbonate," and when purified by re-crystallisation is called "pearl-ash." Nitrate and chloride of potassium occur in large quantities in various localities, as deposits upon or within the earth. Sea-water is another source of these compounds.

POTASSIUM WITH OXYGEN forms three compounds, viz. :—

(1.) Potassium monoxide, K_2O;
(2.) Potassium dioxide, K_2O_2;
(3.) Potassium tetroxide, K_2O_4.

POTASSIUM MONOXIDE, K_2O,

Is a greyish-white, brittle substance, volatilising only at very high temperatures. It combines with water, evolving great heat, and producing potassium hydroxide (KHO). Thus—

$$K_2O + H_2O = 2KHO.$$

Preparation.—(1). By exposing thin pieces of potassium to dry air, oxidation rapidly taking place.

(2) By the action of potassium (K) upon potassium hydroxide (KHO). Thus—

$$KHO + K = H + K_2O.$$

Hydrogen and potassium monoxide are formed.

---

* Impregnated with potassium.

POTASSIUM DIOXIDE, K_2O_2,

Is produced during the formation of the following substance—K_2O_4. It has never been obtained pure.

POTASSIUM TETROXIDE, K_2O_4,

Is of a chrome-yellow colour, prepared by the combustion of potassium in dry oxygen. Thus—

$$K_2 + O_4 = K_2O_4.$$

CAUSTIC POTASH. POTASSIUM HYDROXIDE, KHO,

Is a white substance, occurring in deliquescent rods or masses. It is soluble in water, is a powerful cautery, and in solution is used for soap-making, and as a test reagent in the laboratory.

It is prepared (1) by the addition of potassium monoxide (K_2O) to water (H_2O). Thus—

$$K_2O + H_2O = 2KHO.$$

(2). By adding potassium carbonate (K_2CO_3) to slaked lime (CaH_2O_2). Thus—

$$K_2CO_3 + CaH_2O_2 = CaCO_3 + 2KHO.$$

Carbonate of lime is precipitated as a heavy powder, and the clear liquid in which the caustic potash is contained is evaporated to dryness, then fused by exposure to a stronger heat and obtained in sticks by being cast into moulds.

POTASSIUM CARBONATE, K_2CO_3,

Termed, commercially, "pearl-ashes," is very soluble in water. It occurs in white deliquescent crystals, possesses a strong alkaline reaction, and is prepared by the lixiviation of wood-ashes, *i.e.*, by boiling out the ashes of plants with water, the solution being subsequently evaporated to dryness, and a pure salt obtained by crystallisation.

POTASSIUM BICARBONATE. POTASSIUM HYDROGEN CARBONATE, $KHCO_3$,

Occurs in white crystals, not so soluble as the preceding compound, requiring four parts of water for its solution, which is nearly neutral to test paper. It is prepared by passing carbon dioxide (CO_2) through potassium carbonate (K_2CO_3) and water (H_2O). Thus—

$$K_2CO_3 + H_2O + CO_2 = 2KHCO_3.$$

POTASSIUM NITRATE. NITRE. SALTPETRE, KNO_3,

Is found as an efflorescence upon the soil of dry, tropical climates, especially that of India, occurring in six-sided rhombic prisms, soluble in seven parts of water. It is prepared artificially by

NITRIFICATION.

In this process animal matter, containing nitrogen, together with wood-ashes and lime, is exposed in heaps to the action of air. Oxidation of the organic matter takes place gradually, nitric acid is formed, and, uniting with the lime and potash, produces nitrate of lime ($Ca2NO_3$) and nitrate of potash (KNO_3). After boiling with water, potassium carbonate (K_2CO_3) is added; this decomposes the nitrate of lime and the nitrate of potash crystallises out.

Nitre is much used in the preparation of *gunpowder*, the best of which should contain nearly two molecules of nitre, three of carbon, and one of sulphur. Upon firing the substance, the decomposition is as follows: nitrogen (N) is liberated, the charcoal (C) combining with the oxygen (O) of the nitre (KNO_3) and the sulphur (S) with the potassium (K), carbonic anhydride (CO_2) and potassium sulphide (K_2S) being formed.* The explosion is due to the large quantities of gas evolved, and the sudden increase of bulk caused by the rapid rise of temperature. Since sufficient oxygen is contained in gunpowder for its combustion, the substance is capable of burning under water or in a closed space.

POTASSIUM CHLORIDE, KCl,

Crystallises in cubes like chloride of sodium or common salt; exists in large quantities in sea-water and in certain saline deposits, as at Stassfurt. It may be prepared by heating potassium chlorate ($KClO_3$). Thus—

$$KClO_3 + \text{heat} = 3O + KCl.$$

Oxygen and chloride of potassium are formed.

POTASSIUM CHLORATE, $KClO_3$.

This salt crystallises in flat tabular crystals which taste like nitre.

It is prepared (1) by the action of chloride of potassium (KCl) upon chlorate of lime ($Ca2ClO_3$). Thus—

$$Ca2ClO_3 + 2KCl = CaCl_2 + 2KClO_3.$$

Chloride of calcium remains in solution, and potassium chlorate crystallises out.

(2) By passing chlorine through a solution of caustic potash.

---

* Thus $2KNO_3 + 3C + S = 2N + 3CO_2 + K_2S$.
The expansion is 1,500 times that of the powder.

POTASSIUM IODIDE, KI.

Opaque milk-white cubes, fusible and anhydrous, prepared

(a) By the addition of iodine (I) to caustic potash (KHO). Thus—

$$6KHO + 61 = 5KI + 3H_2O + KIO_3.$$

Iodide of potassium, water, and iodate of potassium result.

(b) Iodate of potassium is acted upon by carbon (C). Thus—

$$2KIO_3 + 3C = 3CO_2 + 2KI.$$

Carbonic anhydride and potassium iodide result.

POTASSIUM BROMIDE, KBr,

Is similar to the iodide, and is prepared in the same manner by substituting bromine for iodine.

POTASSIUM SULPHATE, K_2SO_4,

Is found in the ashes of land and sea plants, and is sparingly soluble in water. It may be obtained in rhombic prisms during the preparation of nitric acid (HNO_3). Thus—

$$2KNO_3 + H_2SO_4 = 2HNO_3 + K_2SO_4.$$

Nitric acid and sulphate of potash result, to the latter of which carbonate of potash is added until effervescence ceases.

POTASSIUM HYDROGEN SULPHATE. POTASSIUM BISULPHATE, $KHSO_4$,

Is a soluble salt occurring in flattened six-sided prisms. It is obtained in the same process as the foregoing by adding to K_2SO_4 more sulphuric acid, then evaporating, drying, re-dissolving and re-crystallising.

POTASSIUM SULPHIDES.

There are five of these compounds, viz. :—

POTASSIUM MONOSULPHIDE, K_2S, the DISULPHIDE, K_2S_2, the TRISULPHIDE, K_2S_3, the TETRASULPHIDE, K_2S_4, and the PENTASULPHIDE, K_2S_5.

All these substances are soluble, and when heated with an acid evolve sulphuretted hydrogen.

POTASSIUM HYDROSULPHATE, KHS,

Is a colourless solution which becomes yellow from absorbing oxygen. It is obtained by passing sulphuretted hydrogen gas through a solution of caustic potash. Thus—

$$KHO + H_2S = H_2O + KHS.$$

Water and potassium hydrosulphate are formed.

Tests for the Potassium Compounds.—(1) All these compounds yield a *violet* colour to flame.

(2) The spectrum of this flame exhibits two bright lines; one in the red, the other in the violet.

(3) Tartaric acid ($H_2C_4H_4O_6$) gives a white precipitate of Cream of Tartar ($KHC_4H_4O_6$), on standing or stirring. The addition of a little alcohol increases the delicacy of this test.

(4) Perchloride of platinum ($PtCl_4$) throws down a yellow granular precipitate, falling slowly, and consisting of potassio-platino-chloride ($KPtCl_5$).

SODIUM—NATRIUM (Natron, soda).

Symbol, Na. Combining weight, 23. Specific gravity, 0·97.

Description and Preparation.—This metal was discovered by Sir Humphry Davy in a similar manner to that by which he obtained potassium. It may be readily prepared by reducing the carbonate of soda in the presence of carbon. The metal distils over when condensed, and is received into rock-oil or naphtha.

Sodium is a silver-white metal, soft and easily cut, the cut surface being at first brilliant, but soon becoming tarnished from the formation of a film of oxide.

When thrown upon water (H_2O) the metal floats, separates the hydrogen and leaves a solution of soda; if the water be heated or thickened with starch, the globule of metal becomes so heated that the hydrogen (sodiuretted*) takes fire and burns with a *yellow* flame.

Sources of the Sodium Compounds.—Spectrum analysis has shown that these compounds are contained in every speck of dust; enormous quantities exist in the primitive granitic rocks. The chief source, however, is sea-water, which contains nearly 3 per cent. of sodium chloride or common salt. At the present time sodium carbonate is manufactured upon an enormous scale from sea-salt.

Sodium with Oxygen forms two compounds, viz.:—

(1) Sodium Monoxide, Na_2O;
(2) Sodium Dioxide, Na_2O_2.

Sodium Monoxide, Na_2O,

Is produced when sodium is oxidized in oxygen or dry air at a low temperature, a white powder being formed; this rapidly absorbs water with the formation of

Sodium Hydroxide (NaHO) or *Soda.*—From this compound the water cannot be separated by heat alone, but the hydroxide may again be converted into the oxide by heating with sodium. Thus—

---

* Impregnated with sodium.

$$NaHO + Na = Na_2O + H.$$

Sodium monoxide and hydrogen result.

Sodium Dioxide, Na_2O_2,

Is formed when sodium is heated in oxygen to 200° C. It is a yellowish-white powder, soluble in water, its solution readily decomposing into oxygen and sodium monoxide.

Caustic Soda. Sodium Hydroxide, NaHO.

A white solid, fusible below red-heat, very soluble in water, powerfully alkaline, a caustic, largely used for making hard soap. It is prepared by boiling lime-water (CaH_2O_2) and carbonate of soda (Na_2CO_3) together, and evaporating down the clear solution. Thus—

$$CaH_2O_2 + Na_2CO_3 = CaCO_3 + 2NaHO.$$

Carbonate of lime and caustic soda are formed.

Sodium Chloride. Common Salt, NaCl,

Occurs in thick beds in various parts of the world. Is also prepared from sea-water by evaporation or freezing; and from certain brine-springs by evaporation. It does not dissolve sensibly more in hot than in cold water.

Sodium Carbonate, Na_2CO_3,

Is known commercially as *Soda-ash*. It is prepared from chloride of sodium by the following processes—

(1) The *Salt-cake* process, viz. :—the manufacture of sodium sulphate (the salt-cake) from common salt. Sulphuric acid (H_2SO_4) is added to common salt (NaCl.) Thus—

$$2NaCl + H_2SO_4 = 2HCl + Na_2SO_4.$$

Hydrochloric acid and sodium sulphate, or the salt-cake, are produced.

(2) The *Soda-ash* process, viz. :—(*a*) the preparation of sodium carbonate, and (*b*) its separation and purification.

(*a*) The Salt-cake (Na_2SO_4) is heated with powdered coal (C). Thus—

$$Na_2SO_4 + 4C = 4CO + Na_2S.$$

Carbonic oxide is given off and sulphide of sodium remains.

(b) The sulphide of sodium (Na_2S) is heated with chalk ($CaCO_3$). Thus—

$$Na_2S + CaCO_3 = CaS + Na_2CO_3.$$

Sulphide of lime and carbonate of soda result.

Sodium Hydrogen Carbonate. Bicarbonate of Soda, $NaHCO_3$.

A white crystalline powder which is readily converted into the carbonate by heating. It is prepared by passing a stream of carbonic acid (H_2CO_3) through the carbonate of sodium (Na_2CO_3). Thus—

$$Na_2CO_3 + H_2CO_3 = 2NaHCO_3.$$

Sodium Nitrate, $NaNO_3$,

Is found in large beds in Northern Chili, and termed Chili Saltpetre. It is used as a manure, and also as a substitute for nitrate of potash in the preparation of nitric acid.

Sodium Sulphate, $Na_2SO_4 + 10H_2O$,

Is known commercially as Glauber's Salts, and in the anhydrous state as salt-cake.

Other important salts are—

Sodium Hyposulphite	$Na_2S_2H_2O_4 + 4H_2O$.
Sodium Biborate, Borax	$Na_2B_4O_7 + 10H_2O$.
Sodium Sulphide	Na_2S.
Monosodic Orthophosphate ...	$NaH_2PO_4 + H_2O$.
Disodic Orthophosphate	$Na_2HPO_4 + 12H_2O$.
Trisodic Orthophosphate	$Na_3PO_4 + 12H_2O$.
Microcosmic salt or Sodium ammonium hydrogen phosphate	$NaNH_4HPO_4 + 4H_2O$
Sodium Metaphosphate	$NaPO_3$.
Sodium Pyrophosphate	$Na_4P_2O_7 + 10H_2O$.
Sodium Silicate	$Na_2SiO_33SiO_2$.

Tests for the Sodium Compounds—

(1) These are all soluble in water except the antimoniate.

(2) Antimoniate of potash[*] throws down a *white* precipitate of antimoniate of soda, providing that the liquid has been previously freed from all bases except the alkalies.

(3) They tinge flame *yellow*.

(4) Their spectrum shows a bright line in the yellow band.

[*] $K_2H_2Sb_2O_7$.

LITHIUM—(Lithos, a stone).

Symbol, L. Combining weight, 7. Specific gravity, 0·59.

Description, Sources, etc.—A soft reddish-white metal. The lightest solid known; prepared by the decomposition of the fused chloride by electricity. It occurs in two minerals called *spodumene* and *petalite*, and in small quantities in almost all waters, in tobacco, milk, and human blood.

All the volatile compounds of lithium give a splendid crimson to flame, and the spectrum presents one bright red line by which the minutest trace of lithium may be detected.

AMMONIUM—(From Jupiter Ammon).

In all the ammoniacal salts the existence of a quasi-metal *Ammonium* (NH_4) is supposed, since, if we substitute this for an atom of sodium or potassium in the alkaline salts, a corresponding ammonium salt is obtained. Thus—

Potassium Chloride	KCl.	Ammonium Chloride	NH_4Cl.
Potassium Nitrate	KNO_3.	Ammonium Nitrate	NH_4NO_3.
Potassium Sulphate	$\left.\begin{matrix}K\\K\end{matrix}\right\} SO_4$.	Ammonium Sulphate	$\left.\begin{matrix}NH_4\\NH_4\end{matrix}\right\} SO_4$.
Potassium Hydrosulphide	$\left.\begin{matrix}K\\H\end{matrix}\right\} S$.	Ammonium Hydrosulphide	$\left.\begin{matrix}NH_4\\H\end{matrix}\right\} S$.

The radical (NH_4) in the free state is a dark-blue liquid possessing a metallic lustre, but only existing under very high pressure, and at a very low temperature, and readily decomposing into hydrogen (H), and ammonia (NH_3).

An amalgam of ammonium may be obtained by placing sodium amalgam ($NaHg$) into a solution of chloride of ammonium (NH_4Cl), when chloride of sodium ($NaCl$) is formed, and the liberated ammonium combines with the mercury to form a light bulky metallic mass (NH_4Hg) which rises to the surface of the liquid, but soon decomposes into mercury (Hg), hydrogen (H) and ammonia (NH_3). The decomposition may be represented thus—

$$NaHg + NH_4Cl = NaCl + NH_4Hg.$$

Sodium amalgam and chloride of ammonium yield chloride of sodium and ammonium amalgam.

AMMONIUM CHLORIDE. SAL-AMMONIAC, NH_4Cl,

Occurs in white tough fibrous masses, difficult to powder, but easily soluble in water; on heating it entirely volatilises without fusion. It is prepared by (1) neutralising the ammoniacal liquor of the gas-works with hydrochloric acid; or, (2) by subliming sulphate of ammonia [$(NH_4)_2SO_4$] with common salt (NaCl). Thus—

$$(NH_4)_2SO_4 + 2NaCl = Na_2SO_4 + 2NH_4Cl.$$

Sulphate of sodium and chloride of ammonium result.

AMMONIUM CARBONATE, $(NH_4)_2CO_3$,

Is a very unstable substance, decomposing in contact with air, with evolution of ammonia.

It is prepared by submitting chloride of ammonium (NH_4Cl) and chalk ($CaCO_3$) to sublimation. Thus—

$$2NH_4Cl + CaCO_3 = CaCl_2 + (NH_4)_2CO_3.$$

Chloride of calcium and carbonate of ammonia are formed.

This $(NH_4)_2CO_3$ absorbs water and carbonic acid gas from the air and passes into the

AMMONIUM HYDROGEN CARBONATE OR BICARBONATE OF AMMONIA, NH_4HCO_3.

The SESQUICARBONATE, $(NH_4)_4H_2(CO_3)_3$ or $N_4H_{18}C_3O_9$, is the salt much used in medicine.

AMMONIUM NITRATE, NH_4NO_3,

Occurs in long transparent elastic needles, very soluble in water, and when heated above 230° C. decomposes into water (H_2O) and nitrous oxide gas (N_2O). It is prepared by the addition of nitric acid to ammonia.

AMMONIUM PHOSPHATE, $(NH_4)_3PO_4$,

Is formed when ammonia and phosphoric acid are mixed in hot concentrated solutions from which, upon cooling, the salt crystallises out. Upon drying, one molecule of ammonium is lost, and thus is obtained the salt $(NH_4)_2HPO_4$, upon boiling which another molecule of ammonium disappears and we obtain the salt $NH_4H_2PO_4$. Upon ignition all these salts leave a residue of metaphosphoric acid (HPO_3).

Microcosmic salt or ammonium sodium hydrogen phosphate, NH_4NaHPO_4 is much used for blow-pipe experiments.*

AMMONIUM SULPHATE, $(NH_4)_2SO_4$,

Occurs in long flat six-sided prisms, very soluble in water. It is prepared by the addition of sulphuric acid to gas-water. It is also a native salt, and is much employed as a manure and for the manufacture of alum.

---

* Since at a high temperature it is converted into sodium metaphosphate, which is valuable as a flux.

AMMONIUM SULPHIDE, $(NH_4)_2S$.

This substance separates out in colourless crystals, when dry sulphuretted hydrogen gas and excess of dry ammoniacal gas are brought together at —18C. At the ordinary temperature this substance loses NH_3 and becomes converted into a crystalline mass of the *hydrosulphide* NH_4HS, a volatile body, and very prone to decompose into ammonia and sulphuretted hydrogen. An aqueous solution is much used as a reagent. This is obtained by saturating aqueous ammonia with sulphuretted hydrogen. The colourless solution soon becomes yellow from the formation of polysulphides of ammonium.

Tests for the Ammonium Compounds—

(1) All the salts are white, are volatilised by heat, and if heated with caustic potash, soda, or lime, yield ammonia gas, known by its pungent odour and alkaline reaction on litmus.

(2) Perchloride of platinum gives a yellow precipitate of ammonio-platino-chloride (NH_4PtCl_5).

(3) Nitrate of silver and a solution of arsenious acid with liquor ammoniæ (NH_4HO) gives a yellow precipitate.

(4) Nessler's test consists in the addition of caustic potash (KHO) together with a solution of mercuric iodide (HgI_2) and potassium iodide (KI) to a solution containing ammonia or any of its salts; a brown colouration or precipitate is instantly produced which consists of dimercur-ammonium-iodide. Thus—

$$4KI + 2HgI_2 + NH_3 + 3KHO = 2H_2O + 7KI + NHg_2I, H_2O.$$

This is a most delicate test.

HYDROXYLAMINE, NH_3O or $N\left\{\begin{matrix}H\\H\\OH\end{matrix}\right.$

This substance may be regarded as an intermediate compound between ammonia and water, or as ammonia NH_3 in which one atom of H is replaced by hydroxyl (OH). It acts as a base and unites with acids to form a well-defined series of salts. An aqueous solution of hydroxylamine has been prepared, and forms an inodorous, colourless liquid with strong alkaline reaction, but hydroxylamine itself has never as yet been isolated. It may be prepared synthetically by the direct union of nascent hydrogen (H) and nitric oxide (N_2O_2). Thus—

$$N_2O_2 + 6H = 2NH_3O.$$

The following are the best known salts of hydroxylamine.

NH_3OHCl	... ...	Hydrochlorate of Hydroxylamine.
$(NH_3O)_2H_2SO_4$	... ...	Sulphate ,, ,,
NH_3OHNO_3	... ...	Nitrate ,, ,,
$(NH_3O)_3H_3PO_4$	.. ...	Phosphate ,, ,,

CÆSIUM—(Cæsius, sky-blue), AND RUBIDIUM—(Rubidus, dark-red).

These metals were discovered by spectrum analysis. They were originally found in the mineral water of Durckheim, but since then have been discovered in many other springs, in varieties of mica, as well as in the ashes of several plants, as the beet-root, tobacco, coffee, grapes. They are prepared by decomposing their fused chlorides by means of electricity.

Cæsium may be separated from rubidium by taking advantage of the greater solubility of the acid tartrate of the former. Cæsium gives two bright lines in the blue of the spectrum. Rubidium gives two bright lines in the red and two in the blue of the spectrum.

General Characteristics of the Metals of the Alkalies.

All the metals of this group are monads. Are soft, volatile at high temperatures and easily fusible. They combine very energetically with oxygen, and decompose water at all temperatures with the formation of basic oxides, which are freely soluble in water, producing powerful caustic alkaline substances termed hydroxides from which it is impossible to expel water by heat. Each metal forms only one chloride, and their carbonates are soluble in water.

Sodium (23), which in its properties stands between potassium (39) and lithium (7), has a combining weight which is the arithmetic mean of the other two. Thus—

$$\frac{39 + 7}{2} = 23.$$

GROUP II.—THE METALS OF THE ALKALINE EARTHS.

CALCIUM. STRONTIUM. BARIUM.

CALCIUM—(Calx, lime).

Symbol, Ca. Combining weight, 40. Specific gravity, 1·58.

Description and Sources.—A light yellow metal, readily oxidizing. When heated in the air it burns with a bright white light forming lime (CaO), the only oxide. In combination calcium forms whole mountain chains, and under the forms of limestone, chalk, and gypsum is very extensively diffused over the earth.

Preparation.—(1) By passing an electric current through the fused chloride ($CaCl_2$).

(2) By heating the iodide of calcium (CaI_2) with sodium (Na). Thus—$CaI_2 + 2Na = 2NaI + Ca$.

CALCIUM WITH OXYGEN forms

CALCIUM OXIDE. LIME, CaO.

Description.—A white caustic infusible substance giving an intense white light in the oxyhydrogen flame.

Preparation.—(1) By heating limestone (the carbonate) $CaCO_3$ in kilns by the aid of coal mixed with the stone. Carbonic anhydride (CO_2) escapes, and quick or caustic lime remains.

(2) By heating carbonate of lime ($CaCO_3$) to redness. Thus—

$$CaCO_3 + \text{heat} = CO_2 + CaO.$$

Lime combines very readily with H_2O, giving out great heat, and precipitating a white powder called *slaked lime* (CaH_2O_2) or calcium hydroxide. This is slightly soluble in water, one part dissolving in 730 parts of cold, but only in 1,800 of boiling water, and forming *lime-water*, which has a great power of absorbing carbonic acid from the air. *Mortar* is a mixture of slaked lime, water and sand,* the lime gradually combining with the silica. *Hydraulic mortars* harden under water, and are prepared by heating impure lime containing clay and silica; silicate of lime and alumina form upon moistening the powder, which then sets to a solid, and is unaffected by water. Lime is used in agriculture,

(1) To destroy excess of vegetable matter in the soil.

(2) To liberate potash for the use of plants by decomposing the silicate in heavy clay soils.

CALCIUM CARBONATE, CaCO₃,

Occurs widely diffused as chalk, limestone, coral and marble; also crystalline as Iceland spar (rhombohedral), and as arragonite (rhombic); this substance is therefore polymorphous or crystallising in different systems.

$CaCO_3$ is almost insoluble in *pure* water, but if the water contain carbonic acid it readily dissolves, causing *temporarily hard water.* Upon boiling the water the carbonic acid is given off, and thus a crust of $CaCO_3$ is deposited. The formation of this crust may be obviated by the addition of sal-ammoniac (NH_4Cl) to the water. Thus—

---

* Sand contains silicic acid or silica (SiO_2).

$$CaCO_3 + 2NH_4Cl = CaCl_2 + (NH_4)_2CO_3.$$

Chloride of calcium and carbonate of ammonia are produced.

Water may be softened by suspending sufficient lime to neutralise the excess of CO_2 in the water hardened by the dissolved carbonate.

Calcium Sulphate, $CaSO_4$.

Occurs as a mineral *Anhydrite* and combined with $2H_2O$ as *gypsum* and *alabaster*. It is soluble in 400 parts of water, and forms a common impurity of spring water, causing *permanent hardness*, since boiling will not remove it. *Plaster of Paris* is formed by the application of moderate heat to gypsum which by this means loses its $2H_2O$, and upon again moistening, the $2H_2O$ is again taken up, and the substance sets to a solid mass.

Chloride of Calcium, $CaCl_2$.

A soluble salt formed from limestone or marble ($CaCO_3$) by the addition of hydrochloric acid (HCl). Thus—

$$CaCO_3 + 2HCl = CO_2 + H_2O + CaCl_2.$$

Carbonic anhydride, water, and chloride of calcium are formed.

Upon evaporating the solution, colourless, needle-shaped crystals of $CaCl_2 + 6H_2O$, the hydrated chloride, are formed. Upon drying, this substance forms a porous mass which absorbs water very greedily, and is used for drying gases.

Bleaching Powder, or Chloride of Lime.

$CaCl_2$, $Ca2ClO$ or $Ca\left\{\begin{matrix}Cl\\ OCl\end{matrix}\right.$ has been described earlier under the head of Chlorine.* Other compounds of calcium are

Calcium Fluoride, or Fluor Spar, CaF_2.
Calcium Phosphate, $Ca_3P_2O_8$.
Calcium Sulphide, CaS.
Calcium Pentasulphide, CaS_5.

Tests for the Calcium Compounds—

(1) The spectrum of calcium contains a number of bright lines of which a green line and an orange line at about an equal distance on each side of the sodium line are the most characteristic.

---

* Part I., p. 33.

(2) Any salt of calcium held on platinum wire in a Bunsen burner flame acquires a bright orange tint.

(3) Oxalate of ammonium gives a white precipitate of oxalate of lime. This is a very delicate test, since by it the $\frac{1}{30,000}$ of a grain of calcium may be detected.

STRONTIUM—(Strontian, a village in Scotland).

Symbol, Sr. Combining weight, 87·5. Specific gravity, 2·54.

Description.—A pale yellow metal, found only in a few mineral deposits, especially as the carbonate (Strontianite) and the sulphate (Celestine). It occurs also in small quantities in certain spring waters, and closely resembles calcium in its properties.

Preparation.—By passing a current of electricity through the fused chloride ($SrCl_2$).

When heated in the air strontium forms

STRONTIUM MONOXIDE, SrO. STRONTIA.

Description and Preparation.—A white substance obtained by decomposing the nitrate of strontia, ($Sr2NO_3$) by heat. With water it evolves great heat, forming the *hydrate*, ($SrO + 9H_2O$), which is soluble in water and greedily absorbs carbonic anhydride.

The carbonate and sulphate of strontia are insoluble in water, and are employed in the preparation of the other salts of this metal. The nitrate of strontia ($Sr2NO_3$), and the chloride ($SrCl_2$) are soluble in water, and are the only salts used in the arts, in which they are employed in preparing *Red Fires.* "Red Fire" is composed of a mixture of 40 parts of $Sr2NO_3$, 10 of chlorate of potash ($KClO_3$), 13 of sulphur (S), and 4 of tri-sulphide of antimony (Sb_2S_3).

Tests for the Strontium Compounds—

(1) The salts of strontium tinge flame carmine-red.

(2) The spectrum shows five or six lines in the red, and (if with the high temperature of the blow-pipe flame) one line in the blue.

(3) Hydrofluosilicic acid gives no precipitate. This acid gives a white precipitate with soluble Barium salts.

(4) Sulphuric acid gives a white precipitate of sulphate of strontia, nearly as insoluble as sulphate of baryta.

BARIUM—(Barus, heavy).

Symbol, Ba. Combining weight, 137. Specific gravity, 1·5.

Description and Sources.—A metallic powder of a pale yellow colour, closely resembling calcium and strontium in its properties. The most common minerals in which barium

occurs are the sulphate, *heavy spar*, and the carbonate or *Witherite*.

Preparation.—By passing a current of electricity through the fused chloride ($BaCl_2$).

BARIUM WITH OXYGEN forms two oxides—

(1) Barium monoxide or baryta, BaO.
(2) Barium dioxide, BaO_2.

BARYTA, BaO,

Is a grey substance, prepared by decomposing the nitrate ($Ba2NO_3$) by heat. It fuses at a high temperature, takes up water with the evolution of great heat and the formation of a crystalline hydrate ($BaH_2O_2 + 8H_2O$). This hydrate is soluble in twenty parts of cold water, and by exposure to air the solution absorbs carbonic anhydride and becomes milky.

BARIUM DIOXIDE, BaO_2.

A grey substance formed by gently heating baryta in a current of oxygen. It is used for preparing hydrogen dioxide * (H_2O_2).

BARIUM CHLORIDE, $BaCl_2$.

A soluble salt, and one of the most important salts of barium. May be prepared from barium carbonate ($BaCO_3$) and hydrochloric acid (HCl). Thus—

$$BaCO_3 + 2HCl = CO_2 + H_2O + BaCl_2.$$

It is much used as a precipitant of sulphuric acid.

BARIUM SULPHATE, $BaSO_4$,

Occurs native as *heavy spar*. Specific gravity, 4·6. Is one of the most insoluble salts known, and may be prepared from a soluble salt of barium by the addition of sulphuric acid. Thus—

$$BaCl_2 + H_2SO_4 = 2HCl + BaSO_4.$$

Hydrochloric acid and sulphate of baryta are formed.

It is employed as a paint, termed *blanc-fixe*, when precipitated, and the native *heavy spar*, when ground, is largely used as an adulterant for white lead.

Other salts of barium are the nitrate ($Ba2NO_3$), a soluble salt; the sulphide (BaS) (obtained by heating $BaSO_4$ with coal), decomposing when added to water into barium hydroxide BaH_2O_2, and hydrosulphide of barium BaH_2S_2, both soluble.

The carbonate ($BaCO_3$), barium silico-fluoride (BaF_2SiF_4),

---

* Part I., p. 14.

(2) Any salt of calcium held on platinum wire in a Bunsen burner flame acquires a bright orange tint.

(3) Oxalate of ammonium gives a white precipitate of oxalate of lime. This is a very delicate test, since by it the $\frac{1}{30,000}$ of a grain of calcium may be detected.

STRONTIUM—(Strontian, a village in Scotland).

Symbol, Sr. Combining weight, 87·5. Specific gravity, 2·54.

Description.—A pale yellow metal, found only in a few mineral deposits, especially as the carbonate (Strontianite) and the sulphate (Celestine). It occurs also in small quantities in certain spring waters, and closely resembles calcium in its properties.

Preparation.—By passing a current of electricity through the fused chloride ($SrCl_2$).

When heated in the air strontium forms

Strontium Monoxide, SrO. Strontia.

Description and Preparation.—A white substance obtained by decomposing the nitrate of strontia, ($Sr2NO_3$) by heat. With water it evolves great heat, forming the *hydrate*, ($SrO + 9H_2O$), which is soluble in water and greedily absorbs carbonic anhydride.

The carbonate and sulphate of strontia are insoluble in water, and are employed in the preparation of the other salts of this metal. The nitrate of strontia ($Sr2NO_3$), and the chloride ($SrCl_2$) are soluble in water, and are the only salts used in the arts, in which they are employed in preparing *Red Fires.* "Red Fire" is composed of a mixture of 40 parts of $Sr2NO_3$, 10 of chlorate of potash ($KClO_3$), 13 of sulphur (S), and 4 of tri-sulphide of antimony (Sb_2S_3).

Tests for the Strontium Compounds—

(1) The salts of strontium tinge flame carmine-red.

(2) The spectrum shows five or six lines in the red, and (if with the high temperature of the blow-pipe flame) one line in the blue.

(3) Hydrofluosilicic acid gives no precipitate. This acid gives a white precipitate with soluble Barium salts.

(4) Sulphuric acid gives a white precipitate of sulphate of strontia, nearly as insoluble as sulphate of baryta.

BARIUM—(Barus, heavy).

Symbol, Ba. Combining weight, 137. Specific gravity, 1·5.

Description and Sources.—A metallic powder of a pale yellow colour, closely resembling calcium and strontium in its properties. The most common minerals in which barium

occurs are the sulphate, *heavy spar*, and the carbonate or *Witherite.*

Preparation.—By passing a current of electricity through the fused chloride ($BaCl_2$).

Barium with Oxygen forms two oxides—

(1) Barium monoxide or baryta, BaO.
(2) Barium dioxide, BaO_2.

Baryta, BaO,

Is a grey substance, prepared by decomposing the nitrate ($Ba2NO_3$) by heat. It fuses at a high temperature, takes up water with the evolution of great heat and the formation of a crystalline hydrate ($BaH_2O_2 + 8H_2O$). This hydrate is soluble in twenty parts of cold water, and by exposure to air the solution absorbs carbonic anhydride and becomes milky.

Barium Dioxide, BaO_2.

A grey substance formed by gently heating baryta in a current of oxygen. It is used for preparing hydrogen dioxide * (H_2O_2).

Barium Chloride, $BaCl_2$.

A soluble salt, and one of the most important salts of barium. May be prepared from barium carbonate ($BaCO_3$) and hydrochloric acid (HCl). Thus—

$$BaCO_3 + 2HCl = CO_2 + H_2O + BaCl_2.$$

It is much used as a precipitant of sulphuric acid.

Barium Sulphate, $BaSO_4$,

Occurs native as *heavy spar.* Specific gravity, 4·6. Is one of the most insoluble salts known, and may be prepared from a soluble salt of barium by the addition of sulphuric acid. Thus—

$$BaCl_2 + H_2SO_4 = 2HCl + BaSO_4.$$

Hydrochloric acid and sulphate of baryta are formed.

It is employed as a paint, termed *blanc-fixe,* when precipitated, and the native *heavy spar,* when ground, is largely used as an adulterant for white lead.

Other salts of barium are the nitrate ($Ba2NO_3$), a soluble salt; the sulphide (BaS) (obtained by heating $BaSO_4$ with coal), decomposing when added to water into barium hydroxide BaH_2O_2, and hydrosulphide of barium BaH_2S_2, both soluble.

The carbonate ($BaCO_3$), barium silico-fluoride (BaF_2SiF_4),

---

* Part I., p. 14.

(2) Any salt of calcium held on platinum wire in a Bunsen burner flame acquires a bright orange tint.

(3) Oxalate of ammonium gives a white precipitate of oxalate of lime. This is a very delicate test, since by it the $\frac{1}{30,000}$ of a grain of calcium may be detected.

STRONTIUM—(Strontian, a village in Scotland).

Symbol, Sr. Combining weight, 87·5. Specific gravity, 2·54.

Description.—A pale yellow metal, found only in a few mineral deposits, especially as the carbonate (Strontianite) and the sulphate (Celestine). It occurs also in small quantities in certain spring waters, and closely resembles calcium in its properties.

Preparation.—By passing a current of electricity through the fused chloride ($SrCl_2$).

When heated in the air strontium forms

STRONTIUM MONOXIDE, SrO. STRONTIA.

Description and Preparation.—A white substance obtained by decomposing the nitrate of strontia, ($Sr2NO_3$) by heat. With water it evolves great heat, forming the *hydrate*, ($SrO + 9H_2O$), which is soluble in water and greedily absorbs carbonic anhydride.

The carbonate and sulphate of strontia are insoluble in water, and are employed in the preparation of the other salts of this metal. The nitrate of strontia ($Sr2NO_3$), and the chloride ($SrCl_2$) are soluble in water, and are the only salts used in the arts, in which they are employed in preparing *Red Fires.* "Red Fire" is composed of a mixture of 40 parts of $Sr2NO_3$, 10 of chlorate of potash ($KClO_3$), 13 of sulphur (S), and 4 of tri-sulphide of antimony (Sb_2S_3).

Tests for the Strontium Compounds—

(1) The salts of strontium tinge flame carmine-red.

(2) The spectrum shows five or six lines in the red, and (if with the high temperature of the blow-pipe flame) one line in the blue.

(3) Hydrofluosilicic acid gives no precipitate. This acid gives a white precipitate with soluble Barium salts.

(4) Sulphuric acid gives a white precipitate of sulphate of strontia, nearly as insoluble as sulphate of baryta.

BARIUM—(Barus, heavy).

Symbol, Ba. Combining weight, 137. Specific gravity, 1·5.

Description and Sources.—A metallic powder of a pale yellow colour, closely resembling calcium and strontium in its properties. The most common minerals in which barium

occurs are the sulphate, *heavy spar*, and the carbonate or *Witherite*.

Preparation.—By passing a current of electricity through the fused chloride ($BaCl_2$).

BARIUM WITH OXYGEN forms two oxides—

(1) Barium monoxide or baryta, BaO.
(2) Barium dioxide, BaO_2.

BARYTA, BaO,

Is a grey substance, prepared by decomposing the nitrate ($Ba2NO_3$) by heat. It fuses at a high temperature, takes up water with the evolution of great heat and the formation of a crystalline hydrate ($BaH_2O_2 + 8H_2O$). This hydrate is soluble in twenty parts of cold water, and by exposure to air the solution absorbs carbonic anhydride and becomes milky.

BARIUM DIOXIDE, BaO_2.

A grey substance formed by gently heating baryta in a current of oxygen. It is used for preparing hydrogen dioxide * (H_2O_2).

BARIUM CHLORIDE, $BaCl_2$.

A soluble salt, and one of the most important salts of barium. May be prepared from barium carbonate ($BaCO_3$) and hydrochloric acid (HCl). Thus—

$$BaCO_3 + 2HCl = CO_2 + H_2O + BaCl_2.$$

It is much used as a precipitant of sulphuric acid.

BARIUM SULPHATE, $BaSO_4$,

Occurs native as *heavy spar*. Specific gravity, 4·6. Is one of the most insoluble salts known, and may be prepared from a soluble salt of barium by the addition of sulphuric acid. Thus—

$$BaCl_2 + H_2SO_4 = 2HCl + BaSO_4.$$

Hydrochloric acid and sulphate of baryta are formed.

It is employed as a paint, termed *blanc-fixe*, when precipitated, and the native *heavy spar*, when ground, is largely used as an adulterant for white lead.

Other salts of barium are the nitrate ($Ba2NO_3$), a soluble salt; the sulphide (BaS) (obtained by heating $BaSO_4$ with coal), decomposing when added to water into barium hydroxide BaH_2O_2, and hydrosulphide of barium BaH_2S_2, both soluble.

The carbonate ($BaCO_3$), barium silico-fluoride (BaF_2SiF_4),

---

* Part I., p. 14.

(2) Any salt of calcium held on platinum wire in a Bunsen burner flame acquires a bright orange tint.

(3) Oxalate of ammonium gives a white precipitate of oxalate of lime. This is a very delicate test, since by it the $\frac{1}{35,000}$ of a grain of calcium may be detected.

STRONTIUM—(Strontian, a village in Scotland).

Symbol, Sr. Combining weight, 87·5. Specific gravity, 2·54.

Description.—A pale yellow metal, found only in a few mineral deposits, especially as the carbonate (Strontianite) and the sulphate (Celestine). It occurs also in small quantities in certain spring waters, and closely resembles calcium in its properties.

Preparation.—By passing a current of electricity through the fused chloride ($SrCl_2$).

When heated in the air strontium forms

STRONTIUM MONOXIDE, SrO. STRONTIA.

Description and Preparation.—A white substance obtained by decomposing the nitrate of strontia, ($Sr2NO_3$) by heat. With water it evolves great heat, forming the *hydrate*, ($SrO + 9H_2O$), which is soluble in water and greedily absorbs carbonic anhydride.

The carbonate and sulphate of strontia are insoluble in water, and are employed in the preparation of the other salts of this metal. The nitrate of strontia ($Sr2NO_3$), and the chloride ($SrCl_2$) are soluble in water, and are the only salts used in the arts, in which they are employed in preparing *Red Fires.* "Red Fire" is composed of a mixture of 40 parts of $Sr2NO_3$, 10 of chlorate of potash ($KClO_3$), 13 of sulphur (S), and 4 of tri-sulphide of antimony (Sb_2S_3).

Tests for the Strontium Compounds—

(1) The salts of strontium tinge flame carmine-red.

(2) The spectrum shows five or six lines in the red, and (if with the high temperature of the blow-pipe flame) one line in the blue.

(3) Hydrofluosilicic acid gives no precipitate. This acid gives a white precipitate with soluble Barium salts.

(4) Sulphuric acid gives a white precipitate of sulphate of strontia, nearly as insoluble as sulphate of baryta.

BARIUM—(Barus, heavy).

Symbol, Ba. Combining weight, 137. Specific gravity, 1·5.

Description and Sources.—A metallic powder of a pale yellow colour, closely resembling calcium and strontium in its properties. The most common minerals in which barium

occurs are the sulphate, *heavy spar*, and the carbonate or *Witherite*.

Preparation.—By passing a current of electricity through the fused chloride ($BaCl_2$).

BARIUM WITH OXYGEN forms two oxides—

(1) Barium monoxide or baryta, BaO.
(2) Barium dioxide, BaO_2.

BARYTA, BaO,

Is a grey substance, prepared by decomposing the nitrate ($Ba2NO_3$) by heat. It fuses at a high temperature, takes up water with the evolution of great heat and the formation of a crystalline hydrate ($BaH_2O_2 + 8H_2O$). This hydrate is soluble in twenty parts of cold water, and by exposure to air the solution absorbs carbonic anhydride and becomes milky.

BARIUM DIOXIDE, BaO_2.

A grey substance formed by gently heating baryta in a current of oxygen. It is used for preparing hydrogen dioxide * (H_2O_2).

BARIUM CHLORIDE, $BaCl_2$.

A soluble salt, and one of the most important salts of barium. May be prepared from barium carbonate ($BaCO_3$) and hydrochloric acid (HCl). Thus—

$$BaCO_3 + 2HCl = CO_2 + H_2O + BaCl_2.$$

It is much used as a precipitant of sulphuric acid.

BARIUM SULPHATE, $BaSO_4$,

Occurs native as *heavy spar*. Specific gravity, 4·6. Is one of the most insoluble salts known, and may be prepared from a soluble salt of barium by the addition of sulphuric acid. Thus—

$$BaCl_2 + H_2SO_4 = 2HCl + BaSO_4.$$

Hydrochloric acid and sulphate of baryta are formed.

It is employed as a paint, termed *blanc-fixe*, when precipitated, and the native *heavy spar*, when ground, is largely used as an adulterant for white lead.

Other salts of barium are the nitrate ($Ba2NO_3$), a soluble salt; the sulphide (BaS) (obtained by heating $BaSO_4$ with coal), decomposing when added to water into barium hydroxide BaH_2O_2, and hydrosulphide of barium BaH_2S_2, both soluble.

The carbonate ($BaCO_3$), barium silico-fluoride (BaF_2SiF_4),

---

* Part I., p. 14.

(2) Any salt of calcium held on platinum wire in a Bunsen burner flame acquires a bright orange tint.

(3) Oxalate of ammonium gives a white precipitate of oxalate of lime. This is a very delicate test, since by it the $\frac{1}{30,000}$ of a grain of calcium may be detected.

STRONTIUM—(Strontian, a village in Scotland).

Symbol, Sr. Combining weight, 87·5. Specific gravity, 2·54.

Description.—A pale yellow metal, found only in a few mineral deposits, especially as the carbonate (Strontianite) and the sulphate (Celestine). It occurs also in small quantities in certain spring waters, and closely resembles calcium in its properties.

Preparation.—By passing a current of electricity through the fused chloride ($SrCl_2$).

When heated in the air strontium forms

STRONTIUM MONOXIDE, SrO. STRONTIA.

Description and Preparation.—A white substance obtained by decomposing the nitrate of strontia, ($Sr2NO_3$) by heat. With water it evolves great heat, forming the *hydrate*, ($SrO + 9H_2O$), which is soluble in water and greedily absorbs carbonic anhydride.

The carbonate and sulphate of strontia are insoluble in water, and are employed in the preparation of the other salts of this metal. The nitrate of strontia ($Sr2NO_3$), and the chloride ($SrCl_2$) are soluble in water, and are the only salts used in the arts, in which they are employed in preparing *Red Fires.* "Red Fire" is composed of a mixture of 40 parts of $Sr2NO_3$, 10 of chlorate of potash ($KClO_3$), 13 of sulphur (S), and 4 of tri-sulphide of antimony (Sb_2S_3).

Tests for the Strontium Compounds—

(1) The salts of strontium tinge flame carmine-red.

(2) The spectrum shows five or six lines in the red, and (if with the high temperature of the blow-pipe flame) one line in the blue.

(3) Hydrofluosilicic acid gives no precipitate. This acid gives a white precipitate with soluble Barium salts.

(4) Sulphuric acid gives a white precipitate of sulphate of strontia, nearly as insoluble as sulphate of baryta.

BARIUM—(Barus, heavy).

Symbol, Ba. Combining weight, 137. Specific gravity, 1·5.

Description and Sources.—A metallic powder of a pale yellow colour, closely resembling calcium and strontium in its properties. The most common minerals in which barium

occurs are the sulphate, *heavy spar*, and the carbonate or *Witherite.*

Preparation.—By passing a current of electricity through the fused chloride ($BaCl_2$).

BARIUM WITH OXYGEN forms two oxides—

(1) Barium monoxide or baryta, BaO.
(2) Barium dioxide, BaO_2.

BARYTA, BaO,

Is a grey substance, prepared by decomposing the nitrate ($Ba2NO_3$) by heat. It fuses at a high temperature, takes up water with the evolution of great heat and the formation of a crystalline hydrate ($BaH_2O_2 + 8H_2O$). This hydrate is soluble in twenty parts of cold water, and by exposure to air the solution absorbs carbonic anhydride and becomes milky.

BARIUM DIOXIDE, BaO_2.

A grey substance formed by gently heating baryta in a current of oxygen. It is used for preparing hydrogen dioxide * (H_2O_2).

BARIUM CHLORIDE, $BaCl_2$.

A soluble salt, and one of the most important salts of barium. May be prepared from barium carbonate ($BaCO_3$) and hydrochloric acid (HCl). Thus—

$$BaCO_3 + 2HCl = CO_2 + H_2O + BaCl_2.$$

It is much used as a precipitant of sulphuric acid.

BARIUM SULPHATE, $BaSO_4$,

Occurs native as *heavy spar*. Specific gravity, 4·6. Is one of the most insoluble salts known, and may be prepared from a soluble salt of barium by the addition of sulphuric acid. Thus—

$$BaCl_2 + H_2SO_4 = 2HCl + BaSO_4.$$

Hydrochloric acid and sulphate of baryta are formed.

It is employed as a paint, termed *blanc-fixe*, when precipitated, and the native *heavy spar*, when ground, is largely used as an adulterant for white lead.

Other salts of barium are the nitrate ($Ba2NO_3$), a soluble salt; the sulphide (BaS) (obtained by heating $BaSO_4$ with coal), decomposing when added to water into barium hydroxide BaH_2O_2, and hydrosulphide of barium BaH_2S_2, both soluble.

The carbonate ($BaCO_3$), barium silico-fluoride (BaF_2SiF_4),

---

* Part I., p. 14.

(3) With borax bead before the blow-pipe, the salts yield an amethyst-red colour to the outer flame, but give no colour to the inner.

(4) These salts, when heated upon platinum foil with carbonate of soda (Na_2CO_3), yield a *bluish-green opaque bead* of sodium manganate (Na_2MnO_4).

FERRUM—IRON.

Symbol, Fe. Combining weight, 56. Specific gravity, 7·8.

Description.—A bright, white metal, exceedingly tough, although soft. Pure metallic iron is found only in very small quantity, and almost alone composing the "Meteoric stones," which are supposed to be of extra-terrestrial origin. The chief ores of this metal are the iron-pyrites (FeS_2), the magnetic oxide (Fe_3O_4), red-hæmatite and Elba-iron (Fe_2O_3), and the carbonate, or clay-ironstone.

In commerce, iron exists in three forms, viz.:

(1) Wrought iron (nearly pure iron).

(2) Cast iron (iron with varying quantities of carbon and silicon).

(3) Steel (iron with less carbon than that needed to form the cast variety).

Pure iron, as powder, may be prepared by moderately heating the oxide in a current of hydrogen gas, and since, when exposed to the air, finely divided iron takes fire, it is necessary to retain it in an atmosphere of hydrogen.

After being uniformly hammered and broken, this metal presents a *crystalline granular* structure, which becomes *fibrous* when rolled into bars, and this fibrous texture, after long-continued vibration, returns to the original crystalline state; hence the accidents that have taken place from the snapping of railway axles.

Some of the compounds and the metal itself are highly magnetic, losing this property when red-hot, and receiving it again on cooling.

Iron in a solid mass will not tarnish in dry air, but when heated it oxidizes in black scales of oxide, and if more strongly heated it takes fire, forming the same black oxide. In water containing a trace of carbonic acid, iron gradually becomes coated with *rust* ($Fe_2O_3 3H_2O$), but in pure water the metal remains unchanged.

IRON MANUFACTURE.

Wrought-iron was at one time manufactured by reducing it from its ore by heating it with coal in a wind furnace and hammering out the resulting spongy mass.

The present method consists in first forming *cast-iron*, and separating out subsequently the carbon and silicon which it contains. The chief source of this cast iron is the clay-ironstone (ferrous carbonate ($FeCO_3$) united with silicate of alumina or clay). This is first submitted to roasting, by which process the carbonic acid is driven off and the ferric oxide formed, the ore being then thrown with coal and limestone into a *blast furnace*, the construction of which is as follows:

THE BLAST FURNACE

Consists of a double cone of strong fire-brick, about 50 feet in height, and from 15 to 18 feet wide at the broadest part. It is closed at the bottom, air being blown in near that part in a powerful blast by means of tuyeres or pipes. The fuel and ore are thrown in at the top, the burning mass sinking down, and the molten mass being drawn off at the bottom. At the lowest part is the hearth, where the melted metal and fused slag collect; the latter, which swims upon the surface of the metal, runs continuously from an aperture in the upper part of the hearth, and the former is from time to time tapped from the bottom of the hearth and cast into pigs (as they are called) in moulds made in the sand. The ferric oxide, in passing from the top to the bottom of the furnace, is first reduced to porous metallic iron by the carbonic oxide gas generated from the burning coal; then, meeting with the clay and lime-stone in a hotter part of the furnace, a slag or fusible silicate is formed, and the heated metal encountering carbon, unites with this to form cast-iron in a fusible form, the silica of which in the hottest part of the furnace is reduced to silicon, and thus cast-iron is formed.

Cast-iron is not a definite chemical compound of carbon and silicon with iron, since the carbon may exist in it as scales of graphite, occasioning the *mottled cast-iron*, or in combination as *white cast-iron*. Sulphur and phosphorus are sometimes found in cast-iron, but these must be looked upon as impurities.

Wrought-iron is obtained from cast-iron by the process of "refining" and "puddling." Here the carbon, silicon, phosphorus and sulphur are burnt out by exposing the heated metal to a current of air in a reverberatory furnace, a coat of oxide gradually accumulating upon the melted cast-iron, which is then rolled into balls. The whole of the carbon passes off as carbonic oxide, the silicon being oxidized to silica, which forms a fusible slag by uniting with the oxide of iron; the phosphorus and sulphur also undergo oxidation. The liquid slag is squeezed out of the balls by hammering, and the mass finally rolled into plates or bars.

Although wrought-iron melts only at a very high temperature and with great difficulty, it becomes soft at a much lower one, and when hot possesses the property of "welding," *i.e.*, two clean surfaces of hot metal when hammered together uniting firmly.

Steel is formed by heating bars of wrought-iron to redness in contact with charcoal; it is then found that the bar, instead of being fibrous, has become fine-grained; it is at the same time more flexible, and capable of taking a fine edge, is more fusible, and contains from one to two per cent. of carbon.

THE BESSEMER PROCESS

Consists in burning away the whole of the silicon in cast-iron by means of a blast of air through the molten metal, and then adding sufficient pure cast-iron to yield enough carbon to convert the whole into steel.

Iron is a tetrad* element, and forms the following oxides. With all tetrads it will be observed that the formulæ are usually written with half their molecular weight. Thus—

Ferrous oxide	FeO.
Ferric oxide	Fe_2O_3.
Black, or Magnetic oxide	Fe_3O_4.

FERROUS OXIDE, FeO,

Has never been prepared pure, since it greedily absorbs oxygen, and forms higher oxides. It may be prepared as a white precipitate in total absence of oxygen, by precipitating a soluble ferrous salt by means of caustic alkali. If oxygen be present, a greenish precipitate is formed. With this oxide the ferrous salts are formed, the most important of which are—

FERROUS SULPHATE—PROTOSULPHATE OF IRON, $FeSO_4 + 7H_2O$,

Commonly called *green vitriol*, or copperas. May be prepared (1) by the addition of sulphuric acid (H_2SO_4) to metallic iron (Fe). Thus—

$$Fe + H_2SO_4 = H_2 + FeSO_4.$$

---

* See p. 59.

Hydrogen and ferrous sulphate being formed; or (2) by slowly oxidising metallic iron (Fe) with iron pyrites (FeS_2). Thus—

$$FeS_2 + Fe + 8O = 2FeSO_4.$$

FERROUS CHLORIDE, $FeCl_2$,

May be prepared by passing dry hydrochloric acid gas (HCl) over hot metallic iron (Fe). Thus—

$$Fe + 2HCl = 2H + FeCl_2.$$

Hydrogen escaping and ferrous chloride being formed.

FERROUS CARBONATE, $FeCO_3$,

Occurs as a mineral, called spathose-iron-ore, and less pure in clay ironstone.

FERROUS SULPHIDE, FeS,

Is a black substance, obtained by fusing together equivalent quantities of iron and sulphur. The disulphide FeS_2 is found in large quantities.

All the ferrous compounds are readily prone to oxidation, passing into the ferric salts.

FERRIC OXIDE, Fe_2O_3,

Sometimes called iron sesquioxide, occurs native as red-hæmatite, and specular-iron-ore; with water it forms brown hæmatite. May be prepared (1) by heating ferrous sulphate to redness, or (2) by adding liquor ammoniæ (NH_4HO) to a solution of ferric chloride (Fe_2Cl_6). Thus—

$$Fe_2Cl_6 + 6NH_4HO = 6NH_4Cl + 3H_2O + Fe_2O_3.$$

Chloride of ammonium, water, and ferric oxide are formed.

With this oxide the ferric salts are formed, the most important of which are the following—

FERRIC CHLORIDE, Fe_2Cl_6.

Obtained in anhydrous brilliant red crystals; by (1) passing chlorine gas over hot metallic iron, or in a hydrated form; by (2) acting upon ferrous chloride ($FeCl_2$) with a mixture of hydrochloric acid (HCl), and nitric acid (HNO_3). Thus—

$$6FeCl_2 + 6HCl + 2HNO_3 = N_2O_2 + 4H_2O + 3Fe_2Cl_6.$$

Nitric oxide, water, and ferric chloride result.

By passing sulphuretted hydrogen (H_2S) through Fe_2Cl_6, a white precipitate of sulphur is produced, together with hydrochloric acid and ferrous chloride. Thus—

$$Fe_2Cl_6 + H_2S = S + 2HCl + 2FeCl_2.$$

FERRIC SULPHATE, $Fe_2(SO_4)_3$

Is obtained as a buff-coloured amorphous mass by acting upon ferrous sulphate ($FeSO_4$) with a mixture of sulphuric acid (H_2SO_4), and nitric acid (HNO_3). Thus—

$$6FeSO_4 + 3H_2SO_4 + 2HNO_3 = 4H_2O + N_2O_2 + 3Fe_2(SO_4)_3.$$

THE MAGNETIC OR BLACK OXIDE, Fe_3O_4,

Occurs native as the mineral *lode-stone*, sometimes called *ferroso-ferric oxide.* It is formed when iron is oxidised at a high temperature in aqueous vapour, air, or oxygen.

FERRIC ACID, H_2FeO_4, ?

Is only known in combination. By fusing together nitrate of potash (KNO_3), and ferric oxide (Fe_2O_3), and placing the result in ice-cold water, a deep amethyst-coloured solution is produced, which contains *potassium ferrate* (K_2FeO_4).

Tests for the Iron Compounds—

For the *Ferrous* salts:

These are of a *light green* colour, and in solution give—

(1) With alkalies, a white precipitate turning *greenish-brown.*

(2) With ferrocyanide of potassium (K_4FeCy_6), a white precipitate passing through *light blue* to dark blue.

(3) With ferricyanide of potassium (K_3FeCy_6), a *dark blue* precipitate.

(4) With sulphuretted hydrogen (H_2S), no precipitate.

(5) With sulphide of ammonium (NH_4HS), a black precipitate.

(6) With sulphocyanide of potassium (KSCy), no precipitate.

(7) With tincture of galls, no precipitate.

For the *Ferric* salts:

These are of a *reddish-brown* colour, and in solution give—

(1) With alkalies, a *foxy-red* precipitate.

(2) With K_4FeCy_6, a *Prussian blue* precipitate.

(3) With K_3FeCy_6, no special precipitate, but usually a green colour.

(4) With H_2S, a precipitate of sulphur (white), and the ferric salts are reduced to the ferrous.

(5) With KSCy, a *blood-red* precipitate.

(6) With tincture of galls, a bluish-black precipitate.

COBALT.

Symbol, Co. Combining weight, 58·7. Specific gravity, 8·5.

Description.—A reddish-white, very tenacious metal, strongly magnetic and infusible. Does not occur native, but is found combined with sulphur and arsenic as tin-white cobalt ($CoAs_2$) and cobalt-glance ($CoAsS$). The cobalt compounds are characterised by their brilliancy of colour; they give a splendid blue tint to glass, and are used as pigments. There are three oxides of cobalt—

(1) The monoxide	CoO.
(2) The sesquioxide	Co_2O_3.
(3) An oxide	Co_3O_4.

The monoxide, with acids, forms a series of salts which when hydrated are pink, and when anhydrous are blue. The sesquioxide forms no salts.

There are two series of salts, the Cobaltous and Cobaltic.

Tests—

For the *Cobaltous* salts:
(1) Liquor potassæ gives a blue precipitate turning red.
(2) Liquor ammoniæ gives a blue, turning brown.
(3) Ferrocyanide of potassium gives a greyish-green.
(4) Sulphide of ammonium gives a black.
(5) Carbonate of ammonia gives a pink.

For the *Cobaltic* salts:
(1) Liquor potassæ gives a dark-brown precipitate.
(2) Liquor ammoniæ gives a brownish-red.
(3) Sulphide of ammonium gives a black.
(4) Carbonate of ammonia gives a green.

Cobalt salts with the borax bead on platinum wire yield a very characteristic blue bead.

NICKEL.

Symbol, Ni. Combining weight, 58·7. Specific gravity, 8·8.

Description.—A white, tenacious metal, strongly magnetic, but losing this property when heated to 350°C.

There are two oxides of nickel—

(1) The monoxide	NiO.
(2) The sesquioxide	Ni_2O_3.

The monoxide gives rise to those nickel salts which possess a green colour.

Tests—

(1) The alkalies and their carbonates give a pale apple-green precipitate.
(2) Ferrocyanide of potassium gives a green precipitate.
(3) Sulphide of ammonium gives a black precipitate.

CHROMIUM—(*Chroma*, colour).

Symbol, Cr. Combining weight, 52·2. Specific gravity, 6·8.

Description.—The chief ore of chromium is the chrome ironstone $FeOCr_2O_3$.

The compounds of chromium are chiefly used in the arts as pigments, since many of them possess fine bright colours. The green of porcelain is communicated by the sesquioxide (Cr_2O_3). Chromium is the most infusible of all the metals: it is prepared by passing sodium vapour (Na) over chromic chloride (Cr_2Cl_6). Thus—$6Na + 2Cr_2Cl_6 = 6NaCl + 4Cr$.

There are four compounds of chromium with oxygen, viz.:

(1) Chromium monoxide	CrO.
(2) Chromium sesquioxide	Cr_2O_3.
(3) Chromo-chromic oxide	$CrOCr_2O_3$.
(4) Chromium trioxide	CrO_3.

The two first oxides are basic, and form corresponding salts.

The third oxide corresponds to the magnetic oxide of iron, and chromium trioxide forms an acid with water—chromic acid (H_2CrO_4)—which neutralises bases forming red or yellow coloured chromates.

There are three potassium chromates known, viz.:

(1) Neutral potassium chromate ...	K_2CrO_4.
(2) Potassium anhydro-chromate, or bichromate	$K_2CrO_4CrO_3$
(3) Potassium dianhydrochromate or terchromate	$K_2CrO_42CrO_3$.

Other salts of Chromium are the Chromic chloride, Cr_2Cl_6, the chromic sulphate, $Cr_2(SO_4)_3$, both insoluble salts. The insoluble chromates are lead chromate, $PbCrO_4$, or chrome yellow; silver chromate, Ag_2CrO_4, a deep-red coloured salt, and barium chromate, $BaCrO_4$, a yellow insoluble powder. Chloro-chromic oxide, CrO_2Cl_2 is a volatile compound, intermediate between chrome trioxide and chromic chloride, and is a dark-red, strongly fuming liquid.

Tests for the Chromium Compounds—

For the *Chromous* salts:

(1) Sulphide of ammonium gives a black precipitate.

(2) Liquor ammoniæ gives a blue precipitate, turning green.

(3) Tungstic acid gives a blue precipitate.

For the *Chromic* salts:

(1) Sulphide of ammonium gives a greyish-green precipitate.

(2) Liquor ammoniæ gives a greyish-green precipitate.

(3) Barium salts give pale yellow precipitates.

(4) Lead salts give bright yellow precipitates.
(5) Mercurous salts give brick-red precipitates.
(6) Silver salts give crimson precipitates.

All the salts of chromium yield with borax and the blowpipe an emerald-green glass in the reducing flame.

General Characteristics of the Iron Group.

These metals are all dyads, except iron, which is a tetrad. They decompose water, like the preceding class, form several oxides, chlorides, and sulphides, and are not volatile at the temperature of our furnaces.

GROUP VI.—THE TIN GROUP.

Titanium, Zirconium, Thorium, Niobium and Tantalum belong to this group, but Tin is the only one employed in the arts, and is therefore the only one here described.

STANNUM (Stan, *Saxon,* a stone)—TIN.

Symbol, Sn. Combining weight, 118. Specific gravity, 7·3.

Description.—A white metal, like silver, soft, and malleable, but possessing no tenacity. Emits a peculiar crackling when bent. Tin melts at 235°C., and does not lose its lustre on exposure to air, but when strongly heated it takes fire, a white powder (stannic oxide), or "putty powder," being formed. Tin is a tetrad.

Sources.—Metallic tin is not found native, and the tin ores are found only in a few localities. The chief sources are the Cornish mines, in which it occurs as tin-stone or tin dioxide; but it is also found in Malacca, Mexico, and Borneo. It is common to find traces of copper, arsenic, and other metals in English tin.

Preparation.—The tin ore is crushed and heated with charcoal and lime; the tin then fuses out.

TIN WITH OXYGEN forms two oxides—

(1) Stannous oxide, SnO.
(2) Stannic oxide, SnO_2.

Stannous oxide (SnO) is a black powder, and forms with acids the stannous salts, the most important of which is stannous chloride, $SnCl_2$. This is termed "the salts" in commerce, and is used as a "mordant." Stannic oxide (SnO_2) occurs as the native tin-stone, but it can be artificially prepared in two conditions, possessing entirely different properties. If nitric acid be added to tin, a white powder* is produced which is insoluble in acids; but if an alkali be added to stannic chloride, a white precipitate of stannic oxide results, and this is easily soluble in acids. The salts formed by the soluble stannic oxide are termed stannates, those produced by the insoluble oxide, meta-stannates. "Tin prepare liquor" is a sodium stannate ($Na_2SnO_3,4H_2O$.)

---

* Meta-Stannic Acid ($H_2Sn_5O_{11}$, $4H_2O$).

Stannic oxide forms with acids the stannic salts, the most important of which is the following: Stannic chloride ($SnCl_4$).

Two sulphides of tin also exist:

(1) Stannous sulphide, SnS, a blackish-grey substance, and

(2) Stannic sulphide, SnS_2, a bright yellow crystalline powder called *Mosaic gold.*

Tests for the Tin compounds—

For the *Stannous* salts:

(1) Sulphuretted hydrogen gives a dark brown precipitate.

(2) Gold chloride gives the beautiful "*purple of Cassius.*"*

(3) The stannous salts have also the property of reducing other metallic solutions. Thus—

$$HgCl_2 + SnCl_2 = HgCl + SnCl_3 = Hg + SnCl_4.$$

The mercuric chloride ($HgCl_2$) is reduced first to white mercurous chloride (HgCl), and finally to black metallic mercury (Hg), the stannous chloride ($SnCl_2$) acquiring more chlorine, and passing into the stannic chloride ($SnCl_4$).

For the *Stannic* salts:

(1) Sulphuretted hydrogen gives a yellow precipitate.

(2) Gold chloride gives *no* precipitate.

GROUP VII.—THE ANTIMONY GROUP.

ANTIMONY. | BISMUTH.

Arsenic is often included in this class, but it has been deemed advisable to place it among the non-metallic elements.

ANTIMONY—STIBIUM.

Symbol, Sb. Combining weight, 122. Specific gravity, 6·71.

Description.—A blueish white, brittle, crystalline metal, melting at 450°C. It undergoes no change in the air at the ordinary temperature, but when heated strongly, takes fire, burning with a white flame, and giving off dense white fumes of antimonic oxide (Sb_2O_5). It is unattacked by diluted sulphuric or hydrochloric acids, but is converted by nitric acid into white insoluble antimonic acid ($HSbO_3$). Alloys of antimony are used extensively in the arts. The most important alloy is type metal (lead and antimony), which contains 17 to 20 per cent. of antimony.

---

*The composition of "purple of Cassius" is not exactly known; it *probably consists of a* mixture of metallic gold and stannic oxide.

ANTIMONY WITH OXYGEN forms three oxides—

(1) Antimonious oxide, or trioxide, Sb_2O_3.
(2) *Antimonious-antimonic oxide, Sb_2O_4.
(3) Antimonic oxide, or pentoxide, Sb_2O_5.

Antimonious oxide (Sb_2O_3) sometimes called antimonious acid, is a white powder, and gives rise to the salts of antimony used in medicine. It is best prepared by decomposing the antimonious chloride ($SbCl_3$) with carbonate of soda (Na_2CO_3). Thus—

$$2SbCl_3 + 3Na_2CO_3 = 3CO_2 + 6NaCl + Sb_2O_3.$$

Carbonic anhydride, common salt, and antimonious oxide result.

Tartar emetic ($KSbC_4H_4O_7$) is prepared from acid tartrate of potash ($KHC_4H_4O_6$) and antimonious oxide (Sb_2O_3), and may be regarded as acid tartrate of potash, the hydrogen of which is replaced by a radical SbO. Thus—

Acid tartrate of potash $= K \; H \; C_4H_4O_6$.
Tartar emetic $= K(SbO)C_4H_4O_6$.

Sources and Preparation.—Metallic antimony is found native, but the chief ore is the trisulphide. By heating the sulphide with about half its weight of metallic iron, ferrous sulphide and metallic antimony are formed; and the metal may be reduced by heating the ore, mixed with coal, in a reverberatory furnace.

Antimonic oxide (called sometimes antimonic acid), Sb_2O_5, is a light straw-coloured powder, losing oxygen at a red heat, and being converted into an intermediate oxide, Sb_2O_3,Sb_2O_5, or $2Sb_2O_4$. Antimonic oxide may be prepared by the action of nitric acid upon antimony, and yields monobasic salts termed antimoniates. It may also be prepared by decomposing the pentachloride with water, and in this mode forms dibasic salts, to which the name of met-antimoniates is given.

Antimonious-antimonic oxide (Sb_2O_4) is prepared by heating the metal in the air until no further change occurs.

Metallic antimony, in fine division, takes fire spontaneously in chlorine gas.

The chlorides of antimony are two in number:

(1) Antimony trichloride, $SbCl_3$,

A buttery mass, prepared by passing chlorine gas over an excess of metallic antimony, and

(2) Antimony pentachloride, $SbCl_5$,

A strongly fuming, mobile liquid, prepared by pouring excess of chlorine over the trichloride of antimony.

There are two sulphides of antimony:

The trisulphide, SbS_3, and the pentasulphide, SbS_5.

* $Sb_2O_3 + Sb_2O_5 = 2Sb_2O_4$.

Antimoniuretted hydrogen (SbH_3) is a gas corresponding to arseniuretted hydrogen (AsH_3). It is given off when zinc and a dilute mineral acid are brought into contact with an antimony salt, exactly in the same manner as arseniuretted hydrogen (AsH_3) is prepared.

Tests for the Antimony Compounds—

(1) Sulphuretted hydrogen gives an *orange* precipitate, soluble in sulphide of ammonium. (This is the *only* orange sulphide.)

(2) The chloride thrown into water gives a white precipitate.

(3) Zinc and iron reduce the antimonial salts to the metallic state as a black powder.

(4) SbH_3 burns and deposits two rings on a white plate held *in* the flame. These rings are soluble in sulphide of ammonium, but not in a solution of chlorinated lime, thus distinguishing the gas from arseniuretted hydrogen.

(5) Infusion of cinchona, and any solution of tannic acid, produces a copious dirty-brown precipitate with the salts of antimony.

BISMUTH (Wismuth, *German*, a beautiful meadow).

Symbol, Bi. Combining weight, 210. Specific gravity, 9·8.

Description, Sources, and Preparation.—A pinkish white, brittle, crystalline metal. Melts at 264°C, and volatilises at a white heat. When heated strongly it burns with a blue flame, and it takes fire when thrown into chlorine gas. Some of the compounds are used in medicine, and some in the arts as pigments.

Bismuth occurs native in small quantities, but its chief ore is the sulphide.

The metal may be procured by the simple exposure of its ore to heat. It forms bivalent, trivalent, and quinquivalent salts.

Bismuth with Oxygen forms two oxides—

(1) Bismuthous oxide, Bi_2O_3.
(2) Bismuthic oxide, Bi_2O_5.

Bi_2O_3 is a pale yellow powder, formed by roasting the metal in the air. Bi_2O_5 is a reddish-brown powder, prepared by dissolving Bi_2O_3 in potash and precipitating the bismuthic oxide by heat and nitric acid.

Sulphide of bismuth, Bi_2S_3, is an insoluble black substance. The trichloride, $BiCl_3$, is formed by heating the metal in chlorine. The salts used in medicine are the subnitrate, $BiNO_4,H_2O$, the carbonate $2(Bi_2CO_5)H_2O$ and the oxide Bi_2O_3. Bismuthic Nitrate $Bi3NO_3,5H_2O$ is a soluble salt.

Tests for the Bismuth Compounds—

(1) Sulphuretted hydrogen gives a black precipitate.

(2) Solutions of these salts become *milky* upon the addition of water, insoluble basic compounds being formed.

(3) Metallic bismuth is easily reduced from its compounds before the blow-pipe as a brittle bead.

General Characteristics of the Antimony Group.

These metals are triads; they form a junction line between the metallic and the non-metallic substances, and are closely allied to phosphorus in their properties.

GROUP VIII.—THE LEAD GROUP.

LEAD—PLUMBUM (means something heavy).

Symbol, Pb. Combining weight, 207. Density, 11·3.

Description.—A blueish white metal, so soft that it can be scratched with the nail, may be drawn out into coarse wire, or hammered into plate, but has little elasticity or tenacity. Lead melts at 334° C. It is a dyad metal. In dry air, the surface of the metal remains bright, but in moist air it soon tarnishes from oxidation, and the oxidising process proceeds rapidly if a small quantity of weak acid, such as carbonic or acetic acid, be present. Lead preserves its lustre in pure water freed from air; but should air be present, then oxide of lead is formed, and by the solution of this in water successive portions of the metal are exposed for oxidation. Waters containing *nitrates* and *chlorides*, or much *free carbonic acid*, are *prone to impregnation* with lead, but the hard waters in which are *sulphates* and *carbonates* may safely be brought in contact with the metal, since a thin deposit of carbonate or sulphate of lead is formed, which prevents further action.

Sources.—Not found native; chiefly obtained from the sulphide of lead or galena, PbS.

Preparation.—By roasting galena in a reverberatory furnace with a small amount of lime to form a fusible slag with any silicious mineral matter present. A portion of the sulphide of lead is oxidised to sulphate ($PbSO_4$), another portion of sulphur comes off as sulphur dioxide (SO_2), and oxide of lead (PbO) is left. The lead sulphate and lead oxide both decompose the remaining sulphide, and sulphur dioxide and metallic lead remain. Thus—

$$(1)\ PbSO_4 + PbS = 2Pb + 2SO_2.$$

$$(2)\ 2PbO + PbS = 3Pb + SO_2.$$

Lead with Oxygen forms three compounds:

(1) PbO, lead monoxide, litharge, a straw-coloured powder.

(2) PbO_2, lead dioxide, the puce-coloured oxide.

(3) Pb_3O_4 ($2PbO + PbO_2$), red lead.

PbO, litharge, or massicot, is prepared in scaly crystals (1) by heating the carbonate of lead to dull redness. Thus—

$$PbCO_3 + \text{heat} = CO_2 + PbO.$$

Or (2) by heating lead in a current of air.

This oxide is soluble in caustic potash (KHO), and forms with acids the important series of lead salts, most of which are white, and the soluble ones are poisons. With silica, PbO forms an easily fusible silicate or glass.

PbO_2, the puce-coloured oxide, is prepared by (1) passing chlorine through the hydrated monoxide (PbH_2O_2). Thus—

$$PbH_2O_2 + 2Cl = 2HCl + PbO_2.$$

Or by (2) digesting red lead (Pb_3O_4) with nitric acid (HNO_3). Thus:

$$Pb_3O_4 + 4HNO_3 = 2H_2O + 2Pb2NO_3 + PbO_2.$$

Water, lead nitrate, and the puce-oxide are formed. PbO_2 forms no salts with acids.

Pb_3O_4 is prepared by heating the monoxide for a long time, and thus acquiring more oxygen. Thus—

$$3PbO + O = Pb_3O_4.$$

Lead nitrate, $Pb2NO_3$, is the most important of the *soluble* lead salts. It is prepared by dissolving the oxide, the carbonate, or metallic Pb, in warm HNO_3. It crystallises in octahedra, dissolves in eight parts of cold water, and when strongly heated yields N_2O_4.

Lead acetate, $Pb(C_2H_3O_2)_2$, or sugar of lead, is also a soluble salt.

Lead carbonate, $PbCO_3$, occurs native as cerusite, and is insoluble.

White Lead is a compound of lead carbonate and lead hydroxide, and it may be represented by the formula $2PbCO_3 + PbH_2O_2$.

Galena, or lead sulphide (PbS), is the chief ore of the metal, and is found native. It may be prepared as a black precipitate by passing H_2S through a solution of a lead salt. Galena has a bright blueish-white metallic lustre, and crystallises in cubes and octahedra.

Lead sulphate ($PbSO_4$) is a white insoluble salt, found native, but prepared artificially by adding H_2SO_4 to a soluble lead salt.

Lead chloride, $PbCl_2$, is prepared by the addition of hydrochloric acid to a solution of nitrate of lead. It dissolves in thirty parts of boiling water, and appears as shining needles on cooling.

Lead iodide, PbI_2, is precipitated as beautiful yellow spangles by mixing together hot solutions of iodide of potassium and nitrate of lead, and allowing the mixture to cool.

Lead chromate, $PbCrO_4$, is a yellow insoluble salt called chrome yellow.

Tests for the Lead Compounds—

(1) Sulphuretted hydrogen gives a black precipitate.
(2) Alkalies give white precipitates (hydrated oxide).
(3) Sulphuric acid gives an insoluble white precipitate.
(4) Iodide of potassium gives a yellow precipitate.
(5) Bichromate of potash gives a yellow precipitate.
(6) Charcoal, sodium carbonate, and the blow-pipe yield the metal which is malleable.

GROUP IX.—THE SILVER GROUP.

COPPER. | MERCURY. | SILVER.

COPPER—CUPRUM (from Cyprus).

Symbol, Cu. Combining weight, 63·5. Specific gravity, 8·93.

Description.—A deep-red-coloured metal, very ductile and malleable, and possessed of much tenacity. Melts at a red heat, and slightly volatilises at a white heat, giving a green tint to the hydrogen flame when that gas is passed over it; one of the best conductors of electricity and heat. This metal does not oxidise in pure dry or moist air at ordinary temperatures, but when heated to redness, it readily oxidises to scales of copper oxide.

Brass is an alloy containing about ⅔ of copper and ⅓ of zinc. The yellow or muntz-metal contains 60 per cent. of copper, and is used for sheathing ships. Bronze, gun-metal, bell-metal, and speculum-metal are alloys of tin and copper in varying proportions. These alloys all possess the remarkable property of being hard and brittle when slowly cooled, but of becoming malleable and soft when suddenly cooled by being dipped when red-hot into cold water.

Sources.—Copper occurs native in North America, and in a few other localities, but it is chiefly obtained from the following ores:

(1) Copper pyrites	$Cu_2S + Fe_2S_3$.
(2) Cuprous sulphide	Cu_2S.
(3) Malachite or the carbonate ...	$CuCO_3, CuH_2O_2$.
(4) Cuprous oxide or the red oxide ...	Cu_2O.

The Cornish mines yield considerable quantities of copper, and Chili and South Australia are rich in copper ores.

Preparation.—(1) By reducing the oxide in a current of hydrogen.

(2) By the electrolytic decomposition of a salt of copper.

Metallic copper is easily prepared on a large scale from the carbonate or oxide, but when the copper pyrites ($Cu_2S + Fe_2S_3$) is employed, the process is more difficult. The ore is then roasted continually, to convert the cuprous sulphide into the oxide, and then sand or silicious slag is added to the ore, which is then roasted in a reverbatory furnace ; the cuprous oxide becomes converted into the cuprous sulphide, and the iron oxidising and uniting with the silica forms a light fusible slag. The impure cuprous sulphide fuses and sinks to the bottom of the furnace, and in this manner a coarse metal or "mat" is formed. By a repetition of the process, pure cuprous sulphide or "fine metal" is produced. In order to free the metallic copper from sulphur, the fine metal is roasted and subsequently fused in the air. In the earlier part of the process, part of the sulphur is burnt off with the formation of cupric oxide (CuO), and at a later period the remainder of the sulphide is acted upon by the oxide forming sulphur dioxide (SO_2), and metallic copper (Cu). Thus—

$$Cu_2S + 2CuO = SO_2 + 4Cu.$$

The last traces of oxide are got rid of by "poling," *i.e.*, stirring up the molten copper with a piece of green wood.

Copper with Oxygen forms two oxides—

(1) The cuprous oxide or red suboxide, Cu_2O.
(2) The cupric oxide or black peroxide, CuO.

Cuprous Oxide, Cu_2O,

Is found native in ruby-red octahedra, but it may be prepared artificially by (1) heating together equal quantities of the black oxide (CuO) and copper filings ; or (2) by boiling a solution of sulphate of copper ($CuSO_4$) and caustic potash (KHO) with glucose, or grape sugar. The black oxide is first precipitated by the caustic potash, and subsequently reduced by the glucose, to a bright red powder. A beautiful ruby-red colour is communicated to glass by cuprous oxide.

All the cuprous compounds rapidly absorb oxygen from the air, and pass into the corresponding cupric salts. Of the cuprous salts the most important is the

Cuprous Chloride, $CuCl$.

This is a white solid, and is remarkable for absorbing carbonic oxide gas.

CUPRIC OXIDE, CuO,

May be obtained (1) by heating copper in the air, or (2) by heating cupric nitrate ($Cu2NO_3$) to redness. This black oxide of copper yields the green and blue cupric salts.

The hydrated cupric oxide, CuH_2O_2 is thrown down as a light blue precipitate when liquor potassæ (KHO) is added to a cupric salt, as for instance, to the sulphate of copper ($CuSO_4$). Thus—

$$CuSO_4 + 2KHO = K_2SO_4 + CuH_2O_2.$$

Sulphate of potash and hydrated cupric oxide are formed.

By boiling the hydrate, the water, H_2O is given off, and the black oxide, CuO, is thrown down.

The most important soluble cupric compounds are the following:

CUPRIC SULPHATE, $CuSO_4$, $5H_2O$.

This is known as "blue vitriol," and is obtained in large blue crystals by the action of heat, sulphuric acid, and water upon metallic copper; when heated to redness, $CuSO_4$, $5H_2O$, loses its water of crystallisation and falls to a white powder.

CUPRIC NITRATE, $Cu2NO_3$, $6H_2O$,

Is obtained in large bluish-green rhomboidal prisms by dissolving copper in nitric acid.

CUPRIC CHLORIDE, $CuCl_2$, $2H_2O$,

Is formed when finely divided metallic copper is placed in chlorine gas, or when CuO is acted upon by hydrochloric acid. It occurs in green needle-shaped crystals, an alcoholic solution of which burns with a peculiar green flame.

Amongst the insoluble cupric salts, are the

CUPRIC SULPHIDE, CuS.

A black precipitate formed by the addition of sulphuretted hydrogen to an acid solution of a copper salt.

CUPRIC CARBONATE, $CuCO_3$, CuH_2O_2.

A green precipitate, not known pure, but always containing the hydrated oxide, and obtained by adding any alkaline carbonate to a copper salt.

CUPRIC ARSENITE, SCHEELE'S GREEN, $CuHAsO_3$.

A bright green powder, obtained by mixing an alkaline arsenite with cupric sulphate.

Tests for the Copper Compounds—

(1) Liquor potassæ gives a pale blue precipitate, turning black on boiling. With sulphate of copper ($CuSO_4$)

(2) Liquor ammoniæ (a few drops of) gives a pale blue precipitate, which is dissolved by excess of ammonia, forming a beautiful *sapphire-blue* solution; a remarkable compound is here formed, the composition of which is $CuSO_4 + 2NH_3$, and this is capable of crystallisation. It may be regarded as ammonium sulphate [$(NH_4)_2SO_4$], in which an atom of dyad copper has replaced two atoms of monad hydrogen. Thus—

$$\left.\begin{matrix} NH_4 \\ NH_4 \end{matrix}\right\} SO_4 \quad \ldots \quad \ldots \quad \ldots \quad \left.\begin{matrix} NH_4 \\ NH_2Cu \end{matrix}\right\} SO_4.$$

(3) Ferrocyanide of potassium gives a *chocolate* precipitate of ferrocyanide of copper.

(4) Sulphuretted hydrogen gives a black precipitate.

(5) A polished steel needle or knife dipped in a solution of copper receives a red coating of metallic copper.

MERCURY—HYDRARGYRUM (Hudor, water, arguros, silver).

Symbol, Hg. Combining weight, 200. Specific gravity, at 0°C., 13·596. Density, 100.

Description.—The only metal liquid at the ordinary temperature. White and volatile. Freezes at −39·4°C., and boils at 350°C.; when pure, mercury does not tarnish in dry or moist air, but above 300°C. it absorbs oxygen and passes into the red oxide. It is a dyad metal, and is largely employed in the processes for extracting silver and gold from their ores. Both the metal and its salts are of great medicinal value.

Sources and Preparation.—Found native, and as the sulphide (cinnabar) in Spain, California, Japan, and China. The cinnabar is roasted; the sulphur is evolved as sulphur dioxide (SO_2), the metal volatilises, and the vapour is condensed in earthen pipes.

MERCURY WITH OXYGEN forms two oxides, viz.—

(1) Mercurous oxide or black suboxide, Hg_2O.
(2) Mercuric oxide or red peroxide, HgO.

MERCUROUS OXIDE (Hg_2O),

Is a dark grey powder, seen also in *black wash*, and is propared by precipitating the mercurous chloride ($HgCl$) by means of liquor potassæ (KHO). Thus—

$$2HgCl + 2KHO = 2KCl + H_2O + Hg_2O.$$

Chloride of potassium, water, and mercurous oxide are formed.

MERCURIC OXIDE, HgO,

Occurs in red crystals, which appear yellow when finely powdered, and may be prepared by (1) heating the mercuric nitrate, or (2) by the addition of liquor potassæ (KHO) to the mercuric nitrate ($Hg2NO_3$). Thus—

$$Hg2NO_3 + 2KHO = 2KNO_3 + H_2O + HgO.$$

Nitrate of potash, water, and mercuric oxide result.

MERCUROUS SULPHIDE, Hg_2S,

Is a black substance, obtained by the addition of sulphuretted hydrogen to a mercurous salt.

MERCURIC SULPHIDE, Vermilion, or Cinnabar, HgS,

Is a red substance, and occurs native, but it may be artificially prepared by heating sulphur and mercury together, or by the addition of an excess of sulphuretted hydrogen to a mercuric salt. In this last method the sulphide is black, but when sublimed it becomes red.

MERCURY WITH CHLORINE forms two chlorides, viz.—

(1) Mercurous chloride, or calomel, $HgCl$.
(2) Mercuric chloride, or corrosive sublimate, $HgCl_2$.

MERCUROUS CHLORIDE, SUBCHLORIDE OF MERCURY, CALOMEL, $HgCl$,

Is a white, insoluble powder, and is prepared—

(1) By heating metallic mercury (Hg) with corrosive sublimate ($HgCl_2$). Thus—

$$Hg + HgCl_2 = 2HgCl.$$

Or (2) (*a*) By adding metallic Hg to the mercuric sulphate ($HgSO_4$). Thus—

$$Hg + HgSO_4 = Hg_2SO_4 \text{ (the mercurous sulphate).}$$

(*b*) Chloride of sodium ($NaCl$) is added to the mercurous sulphate (Hg_2SO_4). Thus—

$$Hg_2SO_4 + 2NaCl = Na_2SO_4 + 2HgCl.$$

Sulphate of sodium and calomel are formed.

The calomel sublimes, and forms a solid cake, which is well washed to get rid of any mercuric chloride that may be formed in the preparation.

MERCURIC CHLORIDE, PERCHLORIDE OF MERCURY, CORROSIVE SUBLIMATE, $HgCl_2$,

Occurs in semi-transparent masses or prisms, soluble in 16 of cold and 3 of boiling water; very poisonous.

It is prepared by the addition of chloride of sodium ($NaCl$) to the mercuric sulphate ($HgSO_4$). Thus—

$$HgSO_4 + 2NaCl = Na_2SO_4 + HgCl_2.$$

Sulphate of sodium and mercuric chloride are formed.

When liquor ammoniæ (NH_4HO) is added to $HgCl_2$, "white precipitate," or HYDRARGYRUM AMMONIATUM, NH_2HgCl, is formed. Thus—

$$HgCl_2 + NH_4HO = H_2O + HCl + NH_2HgCl.$$

Water, hydrochloric acid, and "white precipitate" result.

MERCUROUS NITRATE, $HgNO_3,2H_2O$,

Is a soluble salt, obtained in efflorescent prisms by the action of diluted nitric acid upon an excess of metallic mercury.

MERCURIC NITRATE, $Hg2NO_3$,

Is obtained by the action of excess of nitric acid upon metallic mercury, or the mercuric oxide.

Tests for the Mercury Compounds—

(1) All the mercurial salts sublime, and can be decomposed by heat.

(2) By charcoal and sodium carbonate, metallic mercury is obtained. (The reduction test.)

(3) Bright copper strips when placed in an acidulated solution become coated with metallic mercury.

(4) Stannous chloride ($SnCl_2$) in excess precipitates the metal (black).

(5) Bright gold or copper moistened with a solution of mercury, and touched with a pointed steel, becomes coated with a white silvery stain.

Tests for the Mercurous Salts—

(1) Liquor calcis (CaH_2O_2), and all the alkalies, throw down a *black* precipitate ("black wash").

(2) Iodide of potassium (KI) gives an *olive green** precipitate.

(3) Chromate of potash (K_2CrO_4) gives a *bright red* precipitate.

(4) Sulphuretted hydrogen gives a *black* precipitate.

Tests for the Mercuric Salts—

(1) Liquor calcis and all the alkalies, except ammonia, give a *yellow* precipitate ("yellow wash").

---

* Mercurous Iodide, HgI.

(2) Liquor ammoniæ gives a *white* precipitate.

(3) Iodide of potassium gives the *scarlet* mercuric iodide (HgI_2), soluble in excess of either re-agent.

(4) Sulphuretted hydrogen in excess gives a *black* precipitate, becoming *red* when sublimed.

SILVER—ARGENTUM (Arguros, silver, from argos, white).

Symbol, Ag. Combining weight, 108. Specific gravity, 10·5.

Description.—A brilliant white metal, a great conductor of electricity and heat, and very ductile. Silver is a monad metal, and is easily dissolved by nitric acid, with the evolution of nitric oxide gas; the metal readily unites with sulphur, forming the black sulphide.

Sources.—Found native, but more generally combined with antimony, sulphur, chlorine, and bromine. Galena, or lead sulphide, also contains small quantities of silver.

Preparation.—The silver ore is roasted in a furnace with common salt, by which means the silver chloride is formed. Iron scraps (Fe) are then added. Thus—

$$6AgCl + 2Fe = Fe_2Cl_6 + 6Ag.$$

Perchloride of iron and metallic silver are formed.

Metallic mercury is then added, and thus a liquid amalgam of silver and mercury is formed. By distilling off the mercury, the silver remains. When silver is melted in the air, it absorbs twenty-two times its bulk of oxygen, the gas being again evolved upon the solidification of the metal. This process is known as "spitting." Silver is usually alloyed with small quantities of copper for preparing articles of plate and coinage. English silver money contains 7·5 per cent. of copper.

SILVER WITH OXYGEN forms three oxides, viz.—

(1) Silver suboxide, Ag_4O, a black powder.

(2) Silver monoxide, Ag_2O, a brown substance obtained by the addition of liquor potassæ to a solution of nitrate of silver.

(3) Silver dioxide, Ag_2O_2, a black powder, prepared when ozone acts upon metallic silver.

SILVER NITRATE, $AgNO_3$,

Is the most important of the *soluble* salts of silver. It is prepared by the action of nitric acid upon metallic silver and evaporating the solution. It then appears as large translucent tabular crystals. Upon heating, nitrate of silver fuses easily, and when cast into sticks it is known by the name of "lunar caustic." It blackens the skin.

SILVER CHLORIDE, AgCl,

Is the most important *insoluble* salt of silver. It occurs native as "horn silver," and may be obtained as a white curdy precipitate when a silver salt and a soluble chloride are brought into contact. By exposure to light, this salt becomes of a purple tint, increasing in shade according to the length of time of its exposure.

Chloride of silver is readily soluble in hyposulphite of sodium.

SILVER BROMIDE, AgBr,

Is a white substance, obtained by adding an alkaline bromide to silver nitrate.

SILVER IODIDE, AgI,

Is a yellow powder.

SILVER SULPHIDE, Ag_2S,

Occurs native as "silver-glance," and may be obtained as a black precipitate by passing sulphuretted hydrogen gas through a solution of a salt of silver.

Tests for the Silver Compounds—

(1) Hydrochloric acid gives a *white* precipitate (AgCl), *soluble* in liquor ammoniæ.

(2) Alkalies (KHO, &c.), give a *brown* precipitate of Ag_2O, soluble in excess of liquor ammoniæ.

(3) Sulphuretted hydrogen gives a black precipitate (Ag_2S), insoluble in sulphide of ammonium.

(4) Iron, copper, and mercury give a white precipitate (Ag).

(5) Chromate or bichromate of potash gives a *brown* precipitate.

(6) Tribasic phosphate of sodium gives a *yellow* precipitate.

General Characteristics of the Silver Group.

Under no circumstances is water decomposed by these metals. They are all oxidised by strong sulphuric and nitric acids. Silver is a monad; but mercury and copper are dyads.

GROUP X.—THE GOLD GROUP.

GOLD. | PLATINUM.

GOLD—AURUM.

Symbol, Au. Combining weight, 197. Specific gravity, 19·3.

Description.—A soft, yellow metal, soluble in nitro-hydrochloric acid, and in selenic acid. A triad metal, and the most malleable of all the metals, since it can be beaten into leaves

$\frac{1}{100,000}$ of an inch in thickness. It remains untarnished in dry or moist air at any temperature, and is unaffected by sulphur.

The *Standard Gold* of England is an alloy of copper and gold, and contains 8·33 per cent. of the former. This alloy is less ductile than the pure metal, but possesses greater fusibility and hardness.

Sources.—Always found in the metallic state. It occurs in the plutonic rocks, but is also found in the sand of most rivers. It is a widely diffused metal, although occurring only in small quantities.

Preparation.—The sand, or "detritus" in which the metal is contained, is washed in a "cradle," and thus the lighter mud is washed away, whilst the heavier gold grains sink to the bottom.

To obtain pure gold, the ordinary metal is dissolved in aqua regia, and thus terchloride of gold is formed ($AuCl_3$), then ferrous sulphate ($FeSO_4$) is added. Thus—

$$2AuCl_3 + 6FeSO_4 = 2Fe_2(SO_4)_3 + Fe_2Cl_6 + 2Au.$$

Ferric sulphate and ferric chloride are formed, and metallic gold is precipitated as a brown powder.

GOLD WITH OXYGEN forms two oxides, viz.—

(1) Aurous suboxide, Au_2O.
(2) Auric trioxide, Au_2O_3.

Neither of these substances forms any salts with acids, but Au_2O_3 unites with bases to form *aurates.* Thus aurate of sodium is $NaAuO_2$.

"*Fulminating Gold*" is prepared by the action of excess of liquor ammoniæ upon a solution of gold. In this process a brownish-yellow powder is thrown down, which when dry and heated to 100°C. explodes very readily when struck by a hammer, or even spontaneously.

AUROUS CHLORIDE, $AuCl$,

Is a white insoluble mass, obtained by heating auric chloride to 235°C.

AURIC CHLORIDE, $AuCl_3$,

Is obtained by dissolving metallic gold in aqua regia.

Tests for the Gold Compounds—

(1) Ferrous sulphate gives a *brown* precipitate of metallic gold.

(2) The blow-pipe gives a metallic bead of gold.

(3) Stannous chloride gives the "*purple of Cassius.*"

PLATINUM (Platina, silver).

Symbol, Pt. Combining weight, 197·4. Specific gravity, 21·5.

Description.—A bright white metal, never tarnishing, very infusible, and only to be melted in the oxy-hydrogen blowpipe flame. A tetrad metal. Is only dissolved by aqua regia. Finely divided metallic platinum is remarkable for its power of condensing gases on its surface.

Sources.—A comparatively rare metal, always occurring native, and generally alloyed with the metals palladium, rhodium, iridium, osmium, and ruthenium.

Preparation.—Platinum was originally prepared by dissolving its ore in aqua regia, and precipitating the metal with chloride of ammonium as ammonio-platino-chloride. When this precipitate is heated, "*spongy*" or finely-divided platinum is formed. If this sponge, when hot, be hammered and forcibly pressed, it gradually assumes a coherent mass by the "*welding*" of the platinum particles.

A method lately adopted has been to melt the ore with the oxyhydrogen blow-pipe in a very powerful furnace. By this means a pure alloy of platinum, rhodium, and iridium is formed, whilst the impurities are volatilised by the intense heat. This pure alloy is harder, and not so easily attacked by acids as the pure platinum.

PLATINUM WITH OXYGEN forms two oxides, viz.—

(1) Platinum monoxide or platinous oxide, PtO.
(2) Platinum dioxide or platinic oxide, PtO_2.

PLATINUM MONOXIDE is a black powder.

PLATINUM DIOXIDE can be prepared as a brown hydrate by the addition of liquor potassæ to a solution of platinum nitrate. Upon heating the hydrate, the anhydrous oxide is first formed, and subsequently the metal is precipitated.

PLATINUM DICHLORIDE, OR PLATINOUS CHLORIDE, $PtCl_2$,

Is an insoluble greenish-grey powder, prepared by heating the following chloride to 200°C.

PLATINUM TETRACHLORIDE, OR PLATINIC CHLORIDE, $PtCl_4$,

Is a red or brown deliquescent mass, obtained by dissolving the metal in aqua regia, and evaporating the solution to dryness.

Tests for the Platinum Compounds—

(1) Sulphuretted hydrogen gives a brown precipitate soluble in excess of sulphide of ammonium.

(2) Metallic zinc throws down metallic platinum.

(3) The platinic chloride ($PtCl_4$) gives a *yellow* granular precipitate (falling slowly) with potash and ammonia, but not with soda, and is of great use in analysis for the separation of potash and soda.

General Characteristics of the Gold Group.

These metals, with silver and mercury, constitute the noble metals. Gold and platinum are not acted upon by nitric acid, but only by chlorine or aqua regia.

Gold is a triad, and platinum a tetrad metal.

ESTIMATION OF SOME OF THE IMPORTANT METALS.

Potassium,	100	parts	of	$KPtCl_5$	contain	15·98	of	K.
Ammonium	,,	,,	,,	NH_4PtCl_5	,,	7·62	,,	NH_3.
Calcium	,,	,,	,,	$CaCO_3$	,,	56·0	,,	CaO.
Strontium	,,	,,	,,	$SrSO_4$	,,	56·52	,,	SrO.
Barium	,,	,,	,,	$BaSO_4$	,,	65·66	,,	BaO.
Magnesium	,,	,,	,,	*$Mg_2P_2O_7$	,,	36·21	,,	MgO.
Zincum	,,	,,	,,	ZnO	,,	80·24	,,	Zn.
Ferrum	,,	,,	,,	Fe_2O_3	,,	70·0	,,	Fe.
Cobaltium	,,	,,	,,	†Cr_3O_4	,,	73·44	,,	Co.
Nickel	,,	,,	,,	NiO	,,	78·67	,,	Ni.
Chromium	,,	,,	,,	Cr_2O_3	,,	68·63	,,	Cr.
Stannum	,,	,,	,,	SnO_2	,,	78·66	,,	Sn.
Plumbum	,,	,,	,,	$PbSO_4$	,,	68·31	,,	Pb.
Cuprum	,,	,,	,,	CuO	,,	79·85	,,	Cu.
Platinum	,,	,,	,,	NH_4PtCl_5	,,	44·17	,,	Pt.

Hydrargyrum is always weighed as Hg.
Aurum ,, ,, ,, ,, Au.

* Pyrophosphate of Magnesium.
† Cobalto-Cobaltic oxide.

APPENDIX.

An *Atom* is the smallest quantity to which an elementary substance can be reduced. It is to be regarded as a definite quantity, and although the atoms of all bodies are assumed to be of the same size, yet they vary greatly in weight. If the atom of hydrogen be taken as the standard of comparison, and counted to weigh 1, then the atom of oxygen will be found to weigh 16; that of nitrogen 14; and that of sulphur 32. These numbers are therefore termed the *atomic weights.* An atom is the smallest quantity that can enter into combination with another element.

An atom *must be united to another atom,* it cannot exist alone as such, and the two (or more as frequently happens) constitute a molecule. Thus H, O, and N are atoms, and can combine with other bodies, but, when free, they combine with one of their own atoms, and actually exist as H_2, O_2, N_2, *i.e.*, as molecules. One atom in union with another forms a molecule, whether the element be the same or not; thus H and H form a molecule of hydrogen; H and Cl = a molecule of HCl, hydrochloric acid; H, C, and N = a molecule of HCN, hydrocyanic acid. A molecule may, however, consist of 2, 3, 4, or even more atoms, as observed in a molecule of water, H_2O (3 atoms), or of ammonia, NH_3 (4 atoms), &c.

Now although atoms combine in certain definite proportions, their power of replacing one another in compound bodies greatly varies; 1 atom of oxygen may replace 2 atoms of hydrogen in any compound; 1 atom of nitrogen will replace 3 of hydrogen: and 1 atom of carbon will take the place of 4 atoms of hydrogen or 2 atoms of oxygen.

This has led to an arrangement into groups showing the power in atoms of replacing each other in chemical compounds, and this is called their *quantivalence.*

The elementary atoms are divided into monads or univalents, dyads or divalents, triads or trivalents, tetrads or tetravalents, pentads or pentavalents, hexads or hexavalents; the elements themselves being termed monatomic, diatomic, triatomic, tetratomic, &c., in accordance with the number of hydrogen atoms which one atom of each can replace, since the atom H is taken as the standard for comparison, and is the typical monad.

The elements of *even* quantivalence, viz.: the dyads, tetrads, and hexads, are called *Artiads*, and those of *uneven* quantivalence, viz.: monads, triads, and pentads, are known as *Perissads.*

Not only can the elements be considered to possess varying atomicity, but so can the groups of elementary substances, acting collectively as elements, and which are termed "*compound radicals,*" viz.: NO_2, SO_2, PO, as will immediately be seen. Nitric acid (HNO_3) may be considered as water (H_2O), in which one atom of H is replaced by a *monad radical,* NO_2. Thus—

$\left.\begin{matrix}H\\H\end{matrix}\right\}O$ water ... ... $\left.\begin{matrix}H\\NO_2\end{matrix}\right\}O$ nitric acid.

Sulphuric acid (H_2SO_4) may be regarded as 2 molecules of water, in which two atoms of H are replaced by the *dyad radical* SO_2. Thus—

$\left.\begin{matrix}H_2\\H_2\end{matrix}\right\}O_2$ water ... ... $\left.\begin{matrix}H_2\\SO_2\end{matrix}\right\}O_2$ sulphuric acid.

Tribasic phosphoric acid (H_3PO_4) may be looked upon as 3 molecules of water, in which 3 atoms of H are replaced by the *triad* radical PO. Thus—

$\left.\begin{matrix}H_3\\H_3\end{matrix}\right\}O_3$ water ... ... $\left.\begin{matrix}H_3\\PO\end{matrix}\right\}O_3$ phosphoric acid.

But although the non-metallic and metallic radicals are classified into univalent and multivalent groups, it must be stated that with the exception of hydrogen, which is always univalent, all the other radicals may exhibit different degrees of quantivalence. Observe the oxides of nitrogen, N_2O, N_2O_2, N_2O_3, N_2O_4, N_2O_5. Here, from the formulæ, nitrogen may range from a monad to a pentad inclusive. Carbon is *tetrad* in marsh gas, CH_4, and in carbonic anhydride, CO_2, but only *dyad* in carbonic oxide, CO. Sulphur is *hexad* in sulphuric anhydride, SO_3, and *dyad* in sulphuretted hydrogen, H_2S. Iron may be *dyad* at one time, as in ferrous chloride, $FeCl_2$, and *tetrad* at another, as in ferric chloride, Fe_2Cl_6; an apparent abnormality to be subsequently explained.*

LAWS REGULATING CHEMICAL COMBINATIONS

Are as follows :—

1*st.* The law of *Constant proportion.*—The same substance always contains the same elements united in the same proportions.

---

* Page 59.

2nd. The law of *Multiple proportion.*—When one body combines with another in several proportions, the higher proportions are always multiples of the first or lowest.

3rd. The law of *Reciprocal proportion.*—If two bodies unite with a third, the proportions in which they combine with that third body are measures or multiples of the proportion in which they combine with each other.

The combining quantity of a compound body is the sum of the combining proportions of its constituents. Thus water, H_2O = 2 for H, and 16 for O = 18, and this is the combining quantity of that fluid; and H_2SO_4, sulphuric acid, would be 2 for H, 32 for S, and 4 times 16 for O, *i.e.*, 64, proving 98 altogether to be its combining proportion, which is the case.

When one atom of an element unites with an atom of another, in several proportions, distinctive names are applied; thus, a metal might unite with oxygen as follows: M_2O, MO, M_2O_3, MO_2, MO_3, MO_4, and to these the terms *suboxide, monoxide, sesquioxide, dioxide, trioxide,* and *tetroxide* would be respectively applied. The resulting compound is always termed an *ide.* If any non-metallic elements were substituted for the oxygen, such as sulphur, iodine, or chlorine, we should have sub-, mono-, sesqui-, di-, tri-, or tetra-, sulphides—iodides, or chlorides, according to the number of atoms of each united with one of the metal.

If an element form two acids, the name of the lower terminates in *ous,* and the higher in *ic,* as nitrous, nitric, sulphurous, sulphuric. If it forms two salts the same rule holds good; thus we have ferrous and ferric salts, mercurous and mercuric, cuprous and cupric, &c. The termination *ous* is synonymous with a proto or sub-salt, and the termination *ic* with a per-salt. Thus the ferr*ous* sulphate ($FeSO_4$) may be called the *proto*sulphate or *sub*sulphate, and the ferr*ic* sulphate ($Fe_2(SO_4)_3$) is termed the *per*sulphate.

It may here be stated that the termination *ic* always implies the presence of more oxygen or of the radical than that contained in *ous,* but that the termination *ide* (unless ox-ide) denotes the absence of oxygen, viz.:

H_2SO_4 (sulphur*ic* acid), H_2SO_3 (sulphur*ous* acid).

H_2S (sulph*ide* of hydrogen, or sulphuretted hydrogen).

In the case of chlorides, bromides, iodides, fluorides, and sulphides, viz.: mercurous and mercuric chlorides, &c., oxygen clearly takes no part at all, and here the *ic* implies a larger amount of the acidulous radical than that contained in *ous.*

The composition of any substance may be determined by two methods, viz.: (1) By synthesis, and—

(2) By analysis. The latter may be of two kinds.

(*a*) Qualitative, merely discovering the ingredients.

(*b*) Quantitative, determining the amount of each ingredient.

A *chemical formula* represents a molecule of an element, or of a compound, and serves the following purposes:

(1) It indicates the elements entering into the formation of the molecule.

(2) It shows the number of atoms in the molecule.

(3) It represents a constant weight of the compound, the molecular weight, *i.e.*, the sum of the weights of the atoms in the molecule.

(4) In bodies capable of volatilising, it indicates two volumes of the substance in a state of gas or vapour.

By *a volume* is meant a measure.

The combining volumes of all elementary gases and vapours are equal, except in the case of arsenic and phosphorus, which are only half those of the other elements in the gaseous condition, and those of cadmium and mercury, which are double those of the other elements.

A *chemical equation* consists of a collection of symbols and formulæ, illustrating the condition of substances before and after the assault of the molecules one upon another, and showing the new substances formed.

A solid is a substance, the integrant molecules of which, though probably not in absolute contact, are more or less immobile.

A liquid is that in which the molecules freely move around each other; it therefore readily assumes the form of any vessel in which it may be placed, and retains that form.

A gas is that in which the molecules are so separated that they seem to have lost all attraction to one another, and to have acquired such a property of repulsion that the only obstacle to their still further separation is the pressure of the surrounding matter.

An *amalgam* implies the combination of two or more metals, one of which must be mercury.

An *alloy* implies a combination of metals in which mercury takes no part.

THE ATOMIC THEORY.

John Dalton was the first to enunciate the law of multiple proportion. He asked himself, "Why do the elements combine only in multiples of their several combining proportions?" and upon this question he theorised as follows:

All matter is composed of minute indivisible particles, and these are called *atoms*. Although these atoms do not all possess the same weight, still their relative weights are represented by the combining weights of the elements; the oxygen atom is considered to be 16 times as heavy as the hydrogen atom, and the weights of the oxygen and nitrogen atoms are as 16 to 14.

He also assumed that chemical combination consisted in the individual atoms approximating one to another, and was thus enabled to explain why compounds must contain their constituents in the combining proportions, or in multiples of their proportions, and in no intermediate proportion.

Take, for instance, the compounds of nitrogen with oxygen. The lowest oxide contains one atom of O combined with 2 atoms of N, thus (N) (N) (O); it is therefore termed nitrogen monoxide, N_2O. The next oxide possible of formation must have an additional atom of oxygen. Thus (N) (N) (O) (O), and this is called nitrogen dioxide, N_2O_2. The next compound possible is (N) (N) (O) (O) (O), or nitrogen trioxide, N_2O_3. The next is (N) (N) (O) (O) (O) (O), or nitrogen tetroxide, N_2O_4; and the next (N) (N) (O) (O) (O) (O) (O), or nitrogen pentoxide, N_2O_5.

An atom being indivisible, no intermediate product can be obtained.

Gravity simply denotes weight. Specific gravity means relative weight, or weight compared to a standard.

Density implies the comparative mass, and is frequently employed synonymously with specific gravity, since the two bear so close a relationship, the weight depending upon the amount of the mass.

*SPECIFIC WEIGHT, DENSITY, OR GRAVITY.

Specific gravity may be defined as *the relative weight of equal volumes of different substances.* Water is taken as the standard of comparison of liquids and solids, and air for gases and vapours. We have to determine the specific gravity of matter in three states, as gas, liquid, and solid.

For Gases.

A glass globe, furnished with a stop-cock, is weighed first full of dry air, then perfectly exhausted by an air pump, and again weighed. The difference gives the weight of the volume of air which the globe contains. We now fill the globe with the gas of which the density is required, and weigh it again, taking care that the changes in pressure and temperature are known. The weight of the empty globe, subtracted from the weight of the globe when filled with gas, gives the weight of gas which the globe contains. Then—

---

* Specific gravity means comparative weight, and density comparative mass; weight and mass are directly proportional to each other.

Weight of air : Weight of gas : : 1 : Density of gas.

And thus we obtain the desired density.

For Vapours.

A small globular flask is taken, the neck drawn out to a fine tube, and the whole accurately weighed. The substance of which the vapour density is required, is introduced by warming the flask, and dipping the end of the neck into the fluid. By the cooling and contraction of the air, some of the liquid pressed upon by the external air is forced into the flask, which is now placed in a bath of oil or mercury heated much above the boiling point of the liquid. When the flask is completely filled with the pure vapour of the substance, the neck is sealed by the blow-pipe, and when cool it is again weighed. Thus we know (1) the weight of the flask full of air, and (2) the weight of the flask full of vapour; but we require to know the weight of the empty flask. Now, if we know the capacity of the globe in cubic centimetres, and the weight of 1 c.c. of air, we can obtain this. We break the point of the neck under mercury, which fluid rushes in and fills the flask, excepting the drop of liquid into which the vapour has condensed. Having replaced this by mercury, the latter is measured carefully, and the capacity of the flask is ascertained. Let us suppose this to be 200 c.c. Then the weight of 200 c.c. of air at the temperature of the room, subtracted from the original weight of the flask full of air, gives the weight of the empty flask; this latter weight, subtracted from the weight of the flask filled with vapour, gives the weight of 200 c.c. of the vapour at the temperature at which the flask was sealed. Upon calculating the weight of 200 c.c. of air at the same temperature, we obtain the proportion—

Weight of air : Weight of vapour : : 1 : Density of vapour.

For Liquids.

A vessel of any convenient size is taken, the weight of which is known, and its increase in weight is determined (1) when filled with water, (2) when filled with the given liquid, at the same temperature. We take a flask with a narrow neck, upon which near its middle a mark is made; the weight of this is carefully ascertained. Pure distilled water is now added to the level of the mark, and the flask again weighed. The difference between this and the original weight gives the weight of water taken. After drying, we again fill the flask up to the mark with the liquid the density of which we require, and the weight is again taken. The difference between this and the original weight, is the weight of a volume of the liquid equal to that of the water. Then—

Weight of water : Weight of liquid : : 1 : Density of liquid.

For Solids.

"A solid immersed in a liquid loses a weight equal to the weight of an equal volume of the liquid." We weigh a piece of the solid in air, and then immerse it in water, and again weigh it in that position. By the difference we obtain the weight of an equal volume of water. Then—

$$\left\{\begin{array}{l}\text{Weight of equal}\\ \text{volume of}\\ \text{water}\end{array}\right\} : \left\{\begin{array}{l}\text{Weight of}\\ \text{substance}\\ \text{in air}\end{array}\right\} :: 1 : \text{Density of substance.}$$

Or otherwise, divide weight in air by loss of weight in water, and the quotient will be the density.

If the solid *be lighter than water*, we must first weigh it in air, and then attach to it a solid, heavy enough to sink it, and the weight of which we have determined in air and water. The difference between the loss of weight of the heavy body alone, when immersed in water, and that of the combination when similarly immersed, will give the weight of a volume of water equal to that of the light body, the density of which can be determined by the proportion above.

If the substance *be soluble in water*, it must be weighed in a fluid which does not dissolve it, and the density of which is known. Then we have :

(1) "The relative weights of equal bulks of the substance, and of the liquid in which it was weighed.

(2) The relative weights of equal bulks of the liquid and of water. Hence the weight of a volume of water equal to that of the substance is obtained as follows :

$$\text{Density of liquid} : 1 :: \left\{\begin{array}{l}\text{Weight of liquid}\\ \text{displaced by the}\\ \text{substance}\end{array}\right\} : \left\{\begin{array}{l}\text{Weight of an}\\ \text{equal volume}\\ \text{of water.}\end{array}\right\}$$

Then the density may be obtained in the usual way."

TABLE OF QUANTIVALENCE OF THE PRECEDING METALS.

Monads.	*Dyads.*	*Triads.*	*Tetrads.*
POTASSIUM	CALCIUM	ALUMINIUM	FERRUM
SODIUM	STRONTIUM	STIBIUM*	STANNUM
LITHIUM	BARIUM	BISMUTHUM*	PLATINUM
AMMONIUM	MAGNESIUM	AURUM	
CÆSIUM	ZINCUM		
RUBIDIUM	CADMIUM		
ARGENTUM	MANGANESIUM*		
	COBALTIUM*		
	NICKEL*		
	CHROMIUM*		
	PLUMBUM		
	CUPRUM		
	HYDRARGYRUM		

*** Manganesium, cobaltium and nickel are frequently considered tetrads, whilst chromium is at times hexad, and stibium and bismuthum are sometimes pentad.**

ADDENDA TO SECOND EDITION.

MOLECULAR WEIGHT.

The *molecular weight* of any body (gaseous, liquid or solid) is the sum of the atomic weights of the elements which compose its molecule; thus, taking Oxygen (O), its molecular weight is 32, for

$$O_2 = 2 \times 16 = 32.$$

The molecular weight of Sulphuric Acid (H_2SO_4) is 98. Thus—

$$\begin{aligned} H_2 &= 2 \times 1 = 2 \\ S &= 32 = 32 \\ O_4 &= 4 \times 16 = 64 \\ &\overline{98} \end{aligned}$$

The molecular weight of Nitrate of Potash (KNO_3) is 101. Thus—

$$\begin{aligned} K &= 39 \times 1 = 39 \\ N &= 14 \times 1 = 14 \\ O_3 &= 3 \times 16 = 48 \\ &\overline{101} \end{aligned}$$

SPECIFIC GRAVITY OF A GAS.

The *specific gravity of a gas* is its weight as compared with the weight of an equal volume of Hydrogen, under the same atmospheric pressure, and at the same temperature.

Hydrogen is taken as the standard, and its specific gravity is represented as unity, or 1.

Now since the molecular weight of H is 2,

$$\text{For. : } H_2 = 1 \times 2 = 2,$$

and its specific gravity is 1, it is evident that the specific gravity is *half* the molecular weight.

This law is true for all gases, simple and compound, viz.:

The specific gravity of any gas is half its molecular weight.

FORMULÆ OF THE ELEMENTS.

Elements contain as a rule two atoms in the molecule, thus the formula of H is H_2, which may be represented graphically as

$$H - H,$$

in which it appears that the bond or affinity of one H atom unites with the bond of the other H atom, a saturated body or molecule being produced.

For Oxygen the formula is O_2, or

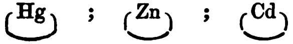
$$O = O,$$

in which it is seen that the two affinities of the one O atom unite with the two affinities of the other O atom.

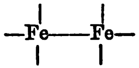
There are six exceptions to the above statement. Thus, the formula for

Mercury	is Hg,	containing	1 atom	in the molecule
Zinc	,, Zn	,,	1 atom	,,
Cadmium	,, Cd	,,	1 atom	,,
Ozone	,, O_2O	,,	3 atoms	,,
Arsenic	,, As_4	,,	4 atoms	,,
Phosphorus	,, P_4	,,	4 atoms	,,

Mercury, zinc and cadmium are dyads, and it may be supposed that the two affinities satisfy each other. Thus—



Some formulæ are to all appearance abnormal. Thus Iron in the ferric salts is classified as a tetrad. The formula for Perchloride of iron or Ferric Chloride is Fe_2Cl_6; here the iron apparently acts as a triad, but it is supposed that an affinity of the one Fe atom is united to an affinity of the other Fe atom, thus leaving only 6 affinities for combination with the chlorine (Cl). Thus—



$$-\overset{|}{\underset{|}{Fe}}-\!\!-\overset{|}{\underset{|}{Fe}}-$$

Upon heating Ferric Chloride this substance becomes a vapour; if the specific gravity of the vapour be taken and doubled, we obtain the molecular weight of Ferric Chloride, and this is found to correspond with the molecular weight yielded by the formula Fe_2Cl_6, and not to that given by $FeCl_3$. Thus, specific gravity of Ferric Chloride vapour = 162·5; on doubling, this gives 325 = molecular weight given by formula Fe_2Cl_6, for

$$\begin{aligned} Fe_2 &= 56 \times 2 = 112{\cdot}0 \\ Cl_6 &= 35{\cdot}5 \times 6 = 213{\cdot}0 \\ \hline & \quad 325{\cdot}0 = \text{molecular weight.} \end{aligned}$$

And 325 ÷ 2 = 162·5 = specific gravity.

Supposing the formula of Ferric Chloride to be $FeCl_3$, the specific gravity of its vapour would be only 81·25, for

$$\begin{aligned} Fe &= \quad 56 \\ Cl_3 &= 35{\cdot}5 \times 3 = 106{\cdot}5 \\ \hline & \quad 162{\cdot}5 \end{aligned}$$

And 162·5 ÷ 2 = 81·25

ATOMICITY OR QUANTIVALENCE

Implies the atom-fixing power of an element, *i.e.*, the saturating or equivalent value contained by the atom of an element, and represented by the number of Hydrogen atoms to which it is equivalent.

A *Bivalent* or *Dyad* element has twice the atom-fixing power of a univalent of monad. For example, water, H_2O; here one atom of dyad Oxygen is united to two atoms of monad Hydrogen.

A *Trivalent* or *Triad* possesses three times the atom-fixing power of a monad. Thus, Chloride of Gold, $AuCl_3$, in which one atom of triad Gold is united with three atoms of monad Chlorine.

A dyad will combine with a triad, but in this case two atoms of the triad must be taken and three of the dyad. Thus in the case of Trioxide of Bismuth, Bi_2O_3, two atoms of triad Bismuth are united with three atoms of dyad Oxygen.

A *Quadrivalent* or *Tetrad* possesses four times the atom-fixing power of a monad, and twice that of a bivalent or dyad. Thus in Perchloride of Platinum, $PtCl_4$, one atom of tetrad Platinum is united to four atoms of monad Chlorine, and in Carbonic Anhydride, CO_2, one atom of tetrad Carbon is united to two atoms of dyad Oxygen.

A *Quinquivalent* or *Pentad* possesses five times the atom-fixing power of a monad. Thus, in Pentachloride of Phosphorus, PCl_5, one atom of pentad Phosphorus is united to five atoms of monad Chlorine. When pentad unites with dyad, two of the former must be taken and five of the latter. Thus, in Pentoxide of Phosphorus, P_2O_5, two atoms of pentad Phosphorus are united to five of dyad Oxygen,

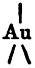
Finally, a *Sexivalent* or *Hexad* possesses six times the atom-fixing power of a monad, and three times that of a dyad. Thus, in Chromium Fluoride, CrF_6, one atom of hexad Chromium is united to six atoms of monad Fluorine, and in Chromic Anhydride, CrO_3, one atom of hexad Chromium is united to three of dyad Oxygen.

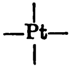
The quantivalence of an element is represented by small dashes or Roman numerals, as follows—

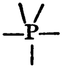
H' ......Univalent, or Monad.
O'' ......Bivalent, or Dyad.
Au''' ...Trivalent, or Triad.
Pt^{iv} ...Quadrivalent, or Tetrad.
P^{v} ......Quinquivalent, or Pentad.
Cr^{vi} ...Sexivalent, or Hexad.

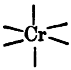
The quantivalence of an element may be thus graphically shown—

H— (one arm, bond, or affinity) ....Monad.
—O— (2 arms, bonds, or affinities) ......Dyad.


(3 ,,) ......Triad.


(4 ,,) ......Tetrad.


(5 ,,) ... ..Pentad.


(6 ,,) ......Hexad.

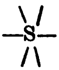
VARIATION OF QUANTIVALENCE.

The following elements possess varying quantivalences, viz.—

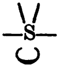
Sulphur (S)
Chromium (Cr)
Manganesium (Mn)
} sometimes acting as Dyad, Tetrad, or Hexad.

Nitrogen (N)	sometimes acting as Monad, Triad, or Pentad.
Phosphorus (P) Arsenicum (As) Antimony (Sb)	„ „ „ Triad and Pentad.
Carbon (C) Iron (Fe) Tin (Sn)	„ „ „ Dyad and Tetrad.

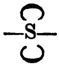
In the first group, to take Sulphur: this substance as a hexad exerts six affinities; thus—


$-\overset{\diagdown\,\diagup}{\underset{\diagup\,\diagdown}{S}}-$ as in Sulphuric Anhydride, $S^{vi}O_3''$;

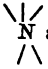
but if two of the six affinities no longer exert their atom-fixing power by grasping one another, *i.e.*, becoming latent, the Sulphur atom will only exert four atom-fixing powers, and then act as a tetrad; thus—


$-\overset{\diagdown\,\diagup}{\underset{\smile}{S}}-$ as in Sulphurous Anhydride, $S^{iv}O_2''$.

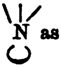
Once more, if two pairs of affinities grasp one another, the Sulphur atom will only exert two atom-fixing powers, and then act as a dyad; thus—


$-\overset{\frown}{\underset{\smile}{S}}-$ as in Sulphuretted Hydrogen, $S''H_2'$.

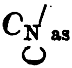
Nitrogen, when exerting full atom-fixing power, is pentad; thus—


$\overset{\diagdown|\diagup}{\underset{\diagup\,\diagdown}{N}}$ as in Nitric Anhydride, $N_2^{v}O_5''$.

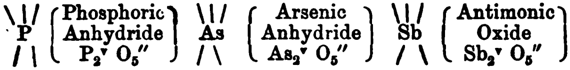
If two affinities become latent, the Nitrogen atom will only act as a triad; thus—


$\overset{\diagdown|\diagup}{\underset{\smile}{N}}$ as in Nitrous Anhydride, $N_2'''O_3''$.

Another pair becoming latent, the nitrogen atom will act as a monad; thus—

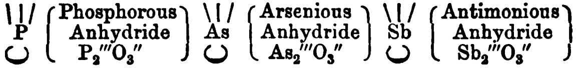

$\overset{\diagup}{\underset{\smile}{{}^{\frown}N}}$ as in Nitrous Oxide, $N_2'O''$.

The preceding remarks are true of Phosphorus, Arsenic, and Antimony, these substances sometimes acting as pentads and sometimes as triads. When acting as pentads, they may be thus represented—



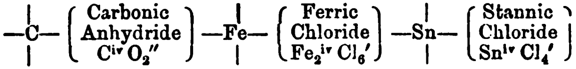
Phosphoric Anhydride $P_2^{v}\,O_5''$ — Arsenic Anhydride $As_2^{v}\,O_5''$ — Antimonic Oxide $Sb_2^{v}\,O_5''$

When acting as triads, thus—



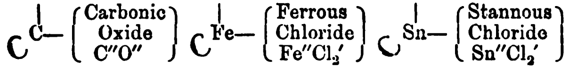
Phosphorous Anhydride $P_2'''O_3''$ — Arsenious Anhydride $As_2'''O_3''$ — Antimonious Anhydride $Sb_2'''O_3''$

Carbon, Iron, and Tin may exert both tetravalent and bivalent atomicities. When acting as tetrads, they may thus be represented—



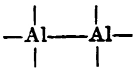
Carbonic Anhydride $C^{iv}O_2''$ — Ferric Chloride $Fe_2^{iv}\,Cl_6'$ — Stannic Chloride $Sn^{iv}\,Cl_4'$

When acting as dyads, thus—



Carbonic Oxide $C''O''$ — Ferrous Chloride $Fe''Cl_2'$ — Stannous Chloride $Sn''Cl_2'$

All Ferric compounds must be represented as containing at least two iron atoms in the molecule. For a like reason the compounds of Aluminium contain two Aluminium atoms in the molecule; and this metal therefore, although apparently acting as a triad, is really a tetrad. In Aluminium Chloride, Al_2Cl_6, the two Aluminium atoms may thus be represented—



$$-\overset{|}{\underset{|}{Al}}-\!\!-\overset{|}{\underset{|}{Al}}-$$

two atoms having grasped or neutralised one another and become latent.

The formulæ of the Mercurous or protosalts of Mercury are apparently abnormal, since the Mercury appears to act as a monad in some salts, *e.g.*, in HgCl, Calomel, and as a dyad in others, *e.g.*, in Corrosive Sublimate, $HgCl_2$; but if we suppose two atoms to be contained in the Mercury molecule, this abnormality may be easily explained, thus—

$$-Hg\!-\!\!-Hg-$$

It would be, therefore, more correct to write the formula for Calomel thus, Hg_2Cl_2, the formula HgCl being doubled.

Mercury in this state is termed a *false* or *pseudo-nomad*, since, being in reality a dyad, it acts to all appearance as a monad.

The formula HgCl has been given to Mercurous Chloride, since the specific gravity of its vapour is 117·75, or half the molecular weight yielded by the formula HgCl, thus—

$$\text{Hg} = 200 + (\text{Cl} = 35\cdot5) = 235\cdot5$$
$$\text{And} \quad 235\cdot5 \div 2 = 117\cdot75$$

This remark is easily reconciled with the undoubtedly correct formula for Calomel or Mercurous Chloride, Hg_2Cl_2, from the fact that when converted into vapour, the Calomel probably splits up into equal volumes of Mercury, Hg, and Mercuric Chloride, $HgCl_2$, and the mean of the specific gravity of the vapour of these substances is 117·75, thus—

(a) $\text{Hg} = 200 + \left\{(\text{Cl}_2 = 35\cdot5 \times 2) = 71\right\} = 271$ and
$271 \div 2 = 135\cdot5 =$ (specific gravity of $HgCl_2$ vapour).
(b) $\text{Hg} = 200$ and
$200 \div 2 = 100 =$ specific gravity of Hg vapour.

$$\begin{array}{ll} 100 & = \text{specific gravity of Hg vapour} \\ 135\cdot5 & = \text{specific gravity of HgCl}_2\ \text{vapour} \\ \hline 235\cdot5 \div 2 = 117\cdot75 & = \text{mean of specific gravities} \\ & \quad \text{of the vapours of HgCl}_2\ \text{and Hg.} \end{array}$$

BASYLOUS AND ACIDULOUS RADICALS.

Every salt consists of two parts, a *Base* or *Basylous Radical* and an *Acid* or *Acidulous Radical, e.g.*, Chloride of Sodium or common salt, NaCl. Here the Na is the basylous radical, and the Cl the acidulous radical. The basylous radical may, however, not only be *simple*, as in this instance, but it may also be *compound*, as observed in the radicals (C_2H_5) Ethyl, (C_5H_{11}) Amyl, etc.

By the term RADICAL is implied a body which is not saturated, but is in need of something with which to combine and become saturated before it can exist. The acidulous radicals can be separated into two groups—

Elementary and Compound Radicals.

The *Elementary* radical consists of an unsaturated element, *e.g.*, Br, the acidulous radical of all Bromides, and it always consists of one atom of the element.

The Chlorine *molecule* is represented by the formula Cl_2, and can exist free, since its two affinities unite and saturate each other. Thus—

$$Cl — Cl.$$

The *radical* Chlorine is represented by the symbol Cl, and cannot exist free, since it is unsaturated, and its affinity uncombined; thus, Cl—. The radical Chlorine must therefore have something to combine with its bond or affinity.

The *Compound* radical is formed by a group of elements not entirely saturating one another, and it must be saturated by some other body or bodies to be capable of existence.

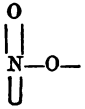
The atomicity or quantivalence of a radical implies its degree of non-saturation; a univalent radical would need one atom of a univalent element to saturate it; the bivalent radical would need two atoms of a univalent element to saturate it, and so on.

1. Examples of univalent acidulous radicals are—

Cl'	the radical of Chlorides.
$(NO_2)'$	„ „ „ Nitrites.
$(NO_3)'$	„ „ „ Nitrates.
$(CN)'$	„ „ „ Cyanides.

The radical of Chlorides is Cl— an atom of the element Chlorine, a univalent element having an uncombined affinity.

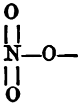
In $N'''O_2''$, the radical of Nitrites, the Nitrogen is only acting as a triad, a pair of its affinities being latent. It is united to two divalent Oxygen atoms; therefore one affinity of Oxygen will be unsaturated, and thus the radical is univalent.



$$\overset{\overset{O}{\|}}{N}—O—$$

The Radical of Nitrites.

In N^vO_3'', the radical of Nitrates, the Nitrogen acts as a pentad, and therefore one affinity of Oxygen is unsaturated, and the radical is univalent.



$$\underset{\underset{O}{\|}}{\overset{\overset{O}{\|}}{N}}—O—$$

The Radical of Nitrates.

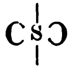
In C N^v, the radical of Cyanides, four affinities of the Nitrogen atom are saturated by four of the Carbon atoms, and therefore one affinity of Nitrogen is unoccupied. The radical is therefore univalent.

$C\equiv N-$ The Radical of Cyanides.

2. Bivalent acidulous radicals—

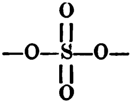
O''	the radical of			Oxides.
S''	„	„	„	Sulphides.
$(SO_4)''$	„	„	„	Sulphates.

The radical of Oxides is —O— an atom of the element Oxygen, a bivalent element having two uncombined affinities. In Sulphides the radical S'' only exerts bivalent atomicity, two pairs of affinities of hexad Sulphur being latent.



The Radical of Sulphides.

In $S^{vi}O_4''$, the radical of Sulphates, two atoms of dyad oxygen are unsaturated, and therefore the radical is bivalent.



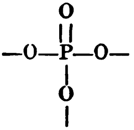
$$-O-\overset{\overset{O}{||}}{\underset{\underset{O}{||}}{S}}-O-$$

The Radical of Sulphates.

3. Trivalent acidulous radicals—

$(PO_4)'''$	the radical of			Phosphates.
$(BO_3)'''$	„	„	„	Borates.

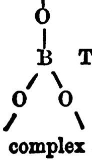
In P^vO_4'' three affinities of Oxygen are uncombined, and therefore the radical is trivalent.



$$-O-\overset{\overset{O}{||}}{\underset{\underset{|}{\underset{O}{|}}}{P}}-O-$$

The Radical of Phosphates.

In $B'''O_3''$, the radical of Borates, three affinities of Oxygen are uncombined; the radical is therefore trivalent.



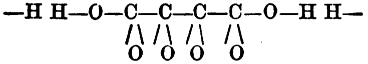
The Radical of Borates.

Among the complex acidulous radicals may be mentioned

$(C_2H_3O_2)'$ the radical of Acetates and $(C_4H_4O_6)''$ the radical of Tartrates.

In $C^{iv}{}_2H'{}_3O''{}_2$, the radical of Acetates, the four affinities of the Oxygen atom and the three affinities of the Hydrogen (together equalling seven) combine and saturate seven of the eight Carbon affinities, leaving one Carbon affinity unsaturated, and making the radical a univalent one.

In $C^{iv}{}_4H'{}_4O''{}_6$, the radical of Tartrates, the Carbon is exercising tetrad quantivalence, but three pairs of its affinities have become latent; thus six affinities have disappeared and ten affinities are left; these satisfy ten of the twelve Oxygen affinities, leaving two Oxygen affinities, and these combine with two of the four Hydrogen affinities, thus leaving two affinities of Hydrogen uncombined, and constituting the radical a bivalent one;—thus:



ACIDS.

According to the old theory of Chemistry, it was supposed that every acid must contain Oxygen, whence the name oxus, acid, gennao, I generate; but according to the new theory of the science, it is held that Hydrogen must enter into the composition of every acid, this Hydrogen being replaceable by a metal in order to form a salt; any acidulous radical combining with its equivalent amount of Hydrogen forms an acid. Should the acid contain one atom of displaceable Hydrogen, it is termed *Monobasic*. Should it contain two atoms, *Dibasic*. If three, *Tribasic*, etc. The so-called Sulphurous Acid (SO_2), and Arsenious Acid (As_2O_3) of the British Pharmacopœia, are erroneously termed acids, since they are destitute of Hydrogen; they are really *Anhydrides*, and are derived from the acids H_2SO_3 and H_3AsO_3, respectively, by the abstraction of the elements of water (H_2O);—thus:

1. $H_2SO_3 - H_2O = SO_2$ and
2. $2H_3AsO_3 - 3\,H_2O = As_2O_3$.

After the naming of a group of acids, it occasionally happens that an acid is discovered which contains more Oxygen than the acid terminating in *ic*. The prefix *per-* abbreviated from

super, above, is then affixed to the acid ending in *-ic*, in order to distinguish it;—thus:

Iodic Acid = HIO_3. *Per*-iodic Acid = HIO_4.

Again, an acid may be discovered which contains a smaller amount of Oxygen than that existing in the acid ending in *-ous*. The prefix *hypo*, under, is then affixed to the acid ending in *ous*;—thus:

Bromous Acid = $HBrO_2$. *Hypo*bromous Acid = $HBrO$.

LATENT HEAT.

Definition.—The heat which is stored up in gases and liquids preventing their change of condition.

It cannot be detected by the thermometer.

If a roll of sulphur be heated, a certain amount of heat is made *latent*, and this keeps the sulphur liquid; if the heating be continued until the sulphur boils, more *latent heat* is required, converting the sulphur into a vaporous or gaseous form. By bringing the vapour into contact with some cool substance, the latent heat is converted into *sensible* heat and the sulphur vapour condenses to a liquid, and further cooling of the liquid sulphur produces solidification of the substance.

Let us consider the conversion of ice into water.

Let 1 lb. of ice at 0° C. be mixed with 1 lb. of water at 79° C.; the result will be 2 lb. of water at 0° C. Here the heat which has raised 1 lb. of water through 79° C. has vanished; it is not, however, lost; it has transformed the pound of ice into a pound of water, and during this operation, the melting ice has rendered the heat latent; it has merely changed the ice from a solid to a liquid state, it has not raised the temperature.

Upon freezing the water, the latent heat is rendered sensible.

SPECIFIC HEAT.

Definition.—The amount of heat required to raise equal weights of different substances having the same temperature to a given degree of temperature.

When 1 lb. of water at 100° is mixed with 1 lb. at 40°, a mean temperature of $\frac{100+40}{2} = 70°$, results. The mean temperature is found in the same way when warm and cold mercury, or warm and cold oil, are mixed together.* "But if 1lb.

---

* Fownes.

of water at 100° be mixed with 1 lb. of olive oil at 40°, or with 1lb. of mercury at 40°, then, instead of the mean temperature of 70°, the temperature actually obtained will be 80° in the first case, 98° in the second; 20 degrees of heat, which the water (by cooling from 100° to 80°), gave to the same weight of oil, were sufficient to raise the oil 40°, that is, from 40° to 80°; and 2°, which the water lost by cooling from 100° to 98°, sufficed to heat an equal quantity of mercury 58°, namely, from 40° to 98°." From these experiments it is evident that the quantities of heat required to raise the temperature of equal weights of water, olive oil, and mercury to the same degree are unequal, and that they are in the proportion of the numbers—

$$1 : \frac{20}{40} : \frac{2}{58}, \text{ or } 1 : \frac{1}{2} : \frac{1}{29}.$$

These experiments show that the specific heat of olive oil is ½, *i.e.*, the quantity of heat which would raise the temperature of any given quantity of olive oil from 0° to 1°, would raise that of an equal weight of water only from 0° to ½°, or of half that quantity of water from 0° to 1°.

The specific heat of various substances may be estimated in three ways—

1st. By noting the quantity of ice melted by a given weight of the substance heated to a particular temperature.

2nd. By observing the time which the heated body requires to cool down through a certain number of degrees.

3rd. The method of mixture as above described, which is considered the most accurate.

Each body then has its peculiar specific heat, which increases with increase of temperature.

If the heat which the unit of water loses when cooled from 10° to 0° be marked at 10°, the loss by cooling from 50° to 0° will not correspond with the difference of temperature, but will be 50·1. By cooling from 100° to 0° it is 100·5, and it rises to 203·2 when the water is heated to 200° under great pressure and afterwards cooled to 0°.

The specific heat of a substance is greater in the liquid than in the solid state, *e.g.*, the specific heat of ice is 0·504, *i.e.*, not more than half as great as that of liquid water.

The specific heat of water is greater than that of all other liquid and solid substances, that of Hydrogen being the only one which exceeds it. The specific heat of the solid part of the globe's crust is upon an average ¼, and that of the atmosphere nearly ¼, that of water. When the specific heat of any body is accurately known (within certain degrees of temperature), then from the amount of heat given off from the body when it is quickly dipped into cold water, the temperature to which the body was heated may be ascertained.

When a gas expands, heat becomes insensible to the thermometer or latent, and the amount of heat requisite to raise a gas to any given temperature increases the more such gas is allowed to expand. The amount of heat requisite for the unit-weight of a gas to raise its temperature 1° without its volume undergoing change, which can only occur by the pressure being simultaneously increased, is termed the specific heat of the gas *at constant volume.*

The amount of heat requisite for the unit-weight of a gas to raise its temperature 1°, it being at the same time permitted to dilate to such an extent that the pressure to which it is exposed remains unaltered, is termed the specific heat of the gas *at constant pressure.* The specific heat, therefore, at constant pressure, must be greater than that at constant volume.

If a gas on expanding is not supplied with requisite heat, its temperature falls, since its own free heat becomes latent, *i.e.*, expended in overcoming pressure. Again, if a gas be compressed, this latent heat becomes free, and produces an elevation of temperature, which may be raised to ignition under favourable circumstances.

THE AIR PUMP

Consists of a metallic cylinder in which a tightly fitting piston moves by means of its rod. The vessel to be exhausted communicates with the bottom of the cylinder, which is furnished with a valve opening upwards. To the piston is fitted a similar valve which also opens upwards. The valves are composed of oiled silk. As soon as the piston is lifted from the bottom of the cylinder, the space which it leaves must be devoid of air, the piston valve opening only in one direction ; the elastic power of the air within the receiver on that side being opposed only by the weight of the little valve, this last is lifted, and the air escapes into the cylinder. When the piston commences its descent, the lower valve shuts by its own weight, or by the pressure transmitted from above, and thus all communication with the receiver is cut off. By the continued descent of the piston the air in the *cylinder* becomes compressed, and its elasticity increased, and at last it forces the upper valve open and escapes into the atmosphere. By this means at every stroke of the pump a cylinder-full of air is removed from the cylinder. During the ascent of the piston the upper valve remains closed and the lower open.

The principle of the air pump depends upon a peculiar physical constitution of gases. These bodies are exceedingly elastic. The space or volume which a gas occupies is entirely dependent upon the pressure to which it is submitted. An air-tight piston, moving in a cylinder closed at the bottom, is pushed down with a certain force; the air below it is compressed into a smaller bulk, and if sufficient power be exerted, the bulk of the gas may be diminished to $\frac{1}{100}$th part or even less.

On the other hand, if the piston standing at the middle of the cylinder (the air beneath it being in its normal state) be drawn upwards, the air below it will expand, entirely filling the increased space. The extent of its possible expansion is apparently unlimited.

A volume of air, under ordinary conditions occupying the bulk of a cubic inch, might, by removing the pressure upon it, be caused to expand to the capacity of an entire room; it would also shrink to its original bulk upon applying the former pressure.

However small the amount of gas introduced into a large exhausted vessel, it becomes diffused through the entire space, an equal quantity existing in every part. The gas fills the vessel also; it is in a state of extreme tenuity.

This indefinite expansibility is supposed to depend on the particles of material bodies in a gaseous state possessing a self repulsive agency.

It is stated that matter is influenced by two opposite forces, one tending to draw the particles together, and the other to separate them. The conditions termed solid, liquid, or gaseous, depend upon the preponderance of one or other of these forces. If the particles possess only a very slight power of motion, a solid substance is presented; if these forces are nearly balanced, a liquid ensues; and if the attractive power is apparently completely vanquished, a vapour or gas results.

The attractive forces receive the name of *cohesion* if exerted between particles of matter divided by an immeasurably small interval. *Gravitation* is the term used when the distance is great.

ELECTRICITY.

The term Electricity is derived from the Greek word *elektron* amber, and may be defined as the peculiar physical agent or force by which, under certain circumstances or conditions, certain phenomena are produced. The chief of these phenomena are those of attraction and repulsion, and in cases where the force exists in great quantity or intensity, of sound, light, heat, chemical action and magnetism.

Thales of Miletus accidentally discovered that when a piece of amber was rubbed by the hand, it acquired the power of at first attracting, and afterwards of supporting minute light substances, which for a time adhered to its surface; and to this circumstance electricity owes its name.

Electricity may be developed or excited in various ways, especially by friction, mechanical and chemical action, heat and magnetism.

It is termed *Frictional* or *Statical Electricity* when developed by friction, concussion, compression, or disruption, and is so named since it tends to remain or *stand* where it is developed, or, having distributed itself over the surface of a body or bodies, there to come to rest.

Thermo-Electricity is the term used when the electricity is developed by heat;

Voltaic or *Galvanic Electricity;* when it is developed by chemical action.

Magneto-Electricity; when developed by magnetism.

The foregoing are essentially the same in kind, and differ only in their relative quantity and intensity.

All bodies when rubbed acquire a power either of electric attraction or of repulsion. When amber, glass, or sealing-wax is rubbed with a dry cloth it acquires the power of attracting light bodies, as dust, pieces of paper, or feathers; the peculiar condition of the rubbed body is termed electrical excitation.

Suspend a light downy feather by a thread and present to it a dry glass tube, previously excited by rubbing; the feather will be powerfully attracted to the tube, and after adhering to its surface for a few seconds, falls off. Now excite the tube afresh, and present the feather to it—it will be powerfully repelled.

The same experiments may be performed with resin or shellac.

Now bring the feather into contact with the excited glass so as to be repelled, and then present to it a piece of excited sealing-wax—a far greater amount of attraction will be observed than that shown by the feather in its ordinary state.

Again, if the feather be made repulsive for sealing-wax, and the excited glass be presented, the feather will be powerfully attracted.

Thus, a body in which one kind of excitement has been induced is attracted by another body in the opposite condition, and repelled by one in the same condition.

Varieties of Electricity. It is usual to term the electricity exhibited by glass rubbed with silk *Vitreous* or *Positive;* that induced in resin or shellac, or like bodies, rubbed with flannel, *Resinous* or *Negative.* The kind of electricity is somewhat dependent on the nature of the surface and the quality of the rubber. If smooth and quite clear glass is rubbed with silk, it becomes positive, but if ground or made rough by emery or sand and then rubbed it becomes negative. Glass when dried over a wood-charcoal fire is positive, but if dried over a gas flame and rubbed with wood it is negative.

The repulsion of bodies in the same state of electrical excitement may be shown by two balls of elder pith hung by very fine metal wires or threads to a fixed point. If these are excited they open out, since they mutually repel one another, and by their degrees of divergence indicate the extent of the excitement.

The Gold Leaf Electroscope consists of a pair of gold leaves suspended by a metal rod, having a brass plate on its upper end. The rod is covered by a thick coat of shellac, and is fastened by an air-tight cork into a glass flask. The flask should be previously warmed in order to ensure its perfect dryness. When excited by any known kind of electricity the gold leaves manifest by their increased or diminished divergence the condition of any electrified body placed in their vicinity.

One kind of electricity cannot be developed without the other; the body rubbed and the rubber always assume opposite conditions. The positive state on the surface of a mass of matter is without exception associated by a negative condition in all bodies surrounding it.

The intensity of the induced electrical disturbance diminishes with its distance from the body charged; if the disturbing agency be removed or discharged, its effects instantly cease.

The apparent transfer or discharge of electricity in air and in liquids often gives rise to a bright spark of fire, and this discharge instantly occurs when any electrified body is placed in communication with the earth by any substance called a *Conductor* of Electricity, every symptom of electrical disturbance ceasing.

An *Insulator* or *Non-Conductor* is a body, the resistance of which is sufficiently great to prevent electricity passing to contiguous bodies. It differs from a conductor quantitatively, *i.e.*, in degree only, not qualitatively or in kind. The electrical discharge is restricted to a certain extent by the best conductors, and permitted to a small extent by the most perfect insulators.

The metals are the best conductors; silk, shellac, glass and dry gas the worst; between these there are bodies of all degrees of conducting power.

Electrical discharges take place silently and without disturbance in good conductors of sufficient size; but if the conductor be very small, and the charge very intense, it is often destroyed violently.

If a break is made in a conductor used in producing the discharge of a highly excited body, and the ends of the conductor are not too distant, disruptive or spark-discharge occurs across the intervening air.

The time occupied in the passage of the wave of electricity through a chain of good conducting substances of great length is so small as to be entirely inappreciable to ordinary methods of observation.

It is only upon the surfaces of conductors, or those parts which are directed towards other objects capable of assuming the opposite condition, that electrical excitation is exhibited.

When an insulated ball charged with positive electricity is placed in the centre of a room, it is kept in the positive condition by the inductive action of the walls of the room, which instantly become charged with negative electricity.

There is no electricity to be found in the interior of the insulated ball, even if constructed of open metal gauze, with wide meshes. On the surface of a body the electrical force is not always similarly distributed; it depends upon the shape of the body itself, and its position with regard to the objects surrounding it.

THE CYLINDRICAL ELECTRICAL MACHINE

Consists of a mounted glass cylinder, its axis being horizontal, and having a handle by which it may be turned. A leather cushion is pressed by a spring against one side of the cylinder, whilst upon the other side is a large metal conducting body furnished with a number of points.

The conductor and cushion are both insulated by glass supports; to the upper edge of the latter a piece of silk is fixed sufficient in length to extend half round the cylinder. A quantity of soft amalgam of mercury, zinc, and tin, mixed with grease (glass is powerfully excited by this mixture), is spread upon the cushion.

As the cylinder turns it becomes charged by friction against the rubber, being as rapidly discharged by the row of points fixed to the conductor, the surface of which, as the conductor is completely insulated, becomes charged with positive electricity. This may be communicated by contact to other insulated bodies.

When negative electricity is required, the rubber must be insulated, and the conductor discharged.

THE COMMON PLATE ELECTRICAL MACHINE

Consists of a circular plate of glass which moves upon an axis, and is furnished with two pairs of cushions or rubbers, fixed to the upper and lower parts of a frame of wood, covered by amalgam, between which the plate moves with much friction. The plate as it turns is discharged by an insulated conductor, armed with points, as in the cylindrical machine, and at the same time the rubber is connected with the ground by a strip of metal or by the woodwork of the machine.

Considerable power is afforded by this apparatus.

THE LEYDEN JAR

Consists of a thin glass jar coated with tinfoil on both sides, several inches of the upper part being uncovered, and a wire, ending in a knot of metal, is in communication with the internal coating.

Upon connecting the exterior of the jar with the earth, the knob being placed in contact with the conductor of the machine, the outer and inner surfaces of the glass become respectively negative and positive, until a considerable amount of intensity is acquired. When the connection is completed between the two coatings by a metallic rod or wire, discharge takes place in the form of an intense bright spark, with a loud snap.

If the size of the jar be increased, or a number of such jars be connected so that all of them may be simultaneously charged and discharged, the power of the apparatus may be much increased.

The effects of lightning on a small scale may be presented, such as the shattering of pieces of wood, the fusing of metals, setting combustible substances on fire, etc.

THE ELECTROPHORUS

Consists of a round dish or tray of tinned plate, a stout wire being attached round its upper edge. The depth may be half an inch and the width about twelve inches. Melted shellac fills the tray, its surface being made as even as possible. A brass disc, about nine inches in diameter, with a rounded edge, is also furnished, in which is fitted an insulating handle.

If a spark is required, the shellac plate is struck with a silk handkerchief or a dry, warm piece of fur, and thus excited; the cover is then placed upon it, and touched by the finger, together with the rim of the plate. Upon raising the cover it will be found charged with positive electricity, and will emit a bright spark.

These sparks may be drawn as often as wanted, since the resin is not discharged by the cover, which is only in contact with it at a few points.

ELECTRIC CURRENT. ELECTRIC BATTERIES.

The simplest form of apparatus for the generation and transmission of a voltaic current consists of

1. A jar of earthenware or glass, containing diluted *sulphuric acid* or a solution of *common salt* (chloride of sodium).
2. A *copper* and a *zinc* plate immersed in the liquid.
3. Two copper wires, one fixed to the *upper* part of each plate.

As soon as the two free ends of the copper wires are brought into contact with each other, a current of *positive* electricity is generated, passing from the zinc, *through* the liquid, to the copper, and over the copper plate, through the wires, towards the zinc. Simultaneously a current of *negative* electricity is thought to proceed from the immersed portion of the copper plate, taking an opposite direction, viz., through the liquid to the zinc plate, and *out* of the cell from the zinc, by its connected wire, towards the copper.

If a strip of unamalgamated zinc be placed in diluted sulphuric acid, bubbles of hydrogen gas immediately arise from its surface. As soon, however, as a strip of copper is dipped into the liquid (care being taken that the metals *do not touch*) no apparent change takes place upon the zinc surface. The plates are now said to be *polarised*, the immersed part of the zinc plate becoming + (positive) and the dry portion — (negative), while the immersed part of the copper plate becomes — and the dry portion +. It has, however, been stated that polarisation is only brought about when the zinc is brought into contact with the copper connecting-wire.

Directly the immersed metals are brought into contact below the surface of the liquid, the hydrogen gas instantly appears, being transferred to the surface of the copper, and escaping very freely from all parts of the surface. Scarcely any hydrogen escapes from the zinc if this metal be fairly pure. If contact be made between the metals *out* of the liquid the same results take place.

The same result occurs when the metals are connected by metallic wires.

If properly amalgamated zinc be used, no hydrogen whatever is evolved from its surface. To amalgamate the zinc, the zinc plate should be dipped into diluted sulphuric acid, a little mercury poured on the plate, and the mercury rubbed over the zinc by means of the end of a stick round which tow has been wrapped.

Thus it is observed that a current of positive electricity is considered to originate or be sustained by the chemical action of the fluid on the zinc, and this current, beginning at the surface of the zinc plate, passes from thence through the liquid to the copper, and back again to the zinc through the copper.

The molecular particles of the liquid through which the current passes are supposed to become *polarised*, and thus become *invisibly transferred.*

The — *copper* plate is supposed to attract and turn towards itself the + hydrogen molecule (H_2) of the water (H_2O); the + *zinc* simultaneously and in like manner attracts and turns towards itself the — *oxygen* molecule (O) of the water (H_2O). Thus—

$$\begin{array}{r} \textit{Before}\text{ the} \\ \text{Current} \end{array}\left\{\begin{array}{l} \mathrm{Cu}\ \overbrace{\mathrm{H_2O}}\ \ \overbrace{\mathrm{H_2O}}\ \ \overbrace{\mathrm{H_2O}}\ \ \mathrm{Zn} \\ \ -\ +\ -\ \ +\ -\ \ +\ -\ \ + \end{array}\right.$$

$$\begin{array}{r} \textit{During}\text{ the} \\ \text{Current} \end{array}\left\{\begin{array}{l} \overbrace{\mathrm{Cu}\ \ \mathrm{H_2}}\ \ \overbrace{\mathrm{OH_2}}\ \ \overbrace{\mathrm{OH_2}}\ \ \overbrace{\mathrm{O\ Zn}} \\ \ -\ \ +\ \ -\ +\ \ -\ +\ \ \ -\ + \end{array}\right.$$

The chemical affinity of the oxygen for the zinc is very powerful. These two substances, therefore, combine to form zinc oxide (ZnO), and this instantly becomes dissolved from the surface of the zinc by the action of the diluted sulphuric acid forming Zinc Sulphate ($ZnSO_4$). If the Zinc Oxide were not dissolved from the surface of the zinc plate, all electric action would terminate.

THE VOLTAIC PILE.

This was the earliest form of battery, and is columnar in arrangement. It consists of a series of zinc and copper discs alternately arranged with layers of cloth or flannel soaked in diluted acid or a solution of common salt, the whole presenting a uniform arrangement, commencing with the zinc as the upper plate and ending with the copper as the lower plate, and thus through the entire series—zinc, copper, flannel;—the terminal plates are connected by wires. Vertical rods of glass are generally used for retaining the discs in their places; and to ensure perfect contact, the zinc and copper discs are usually soldered together.

The electricity thus developed was considered by Volta to be due to the contact of the two dissimilar metals, the moist flannel being merely a conductor.

Although the action of a large Voltaic Pile is at first extremely powerful, it soon becomes comparatively feeble, since the acid is constantly squeezed from between the plates.

By means of this pile, amongst other effects, electric shocks may be given. Sparks may be produced between two pieces of charcoal fixed to the ends of the wires connecting the terminal plates, and the gold leaves of an electroscope may be made to diverge.

THE CROWN OF CUPS—COURONNE DES TASSES.

This was the second form of battery invented by Volta. It consists of a series of glass cups or cells arranged in a circle. In each cell is contained diluted acid, in which are immersed plates of zinc and copper. The plates are alternately arranged, so that the zinc plate of the one vessel is connected by a wire with the copper plate of the next vessel on the one side, the copper plate of that vessel being connected with the zinc plate of the next vessel on the other side of it. If the circuit is closed, the terminal copper and zinc plates are united by their respective wires.

This battery is superior to the Voltaic Pile, since its action continues comparatively uniform for some time, on account of the plentiful supply of the exciting fluid, which is not (as in the case of the pile) squeezed rapidly from the plates by gravity.

THE DRY PILE OF DE LUC

Consists of a series of several hundred circular discs of paper, one side being covered by very thin tin or zinc foil, and the other side by a rubbing of peroxide of manganese, the whole being enclosed by a glass tube terminated by metallic caps. At the manganese end of the pile positive electricity is developed, and from the zinc end negative electricity.

By a dry pile of this description, consisting of 2,000 to 20,000 discs, electric sparks may be produced, electric bells rung for many months continuously, and many other phenomena exhibited.

SMEE'S BATTERY.

Here the negative plate is polarised by mechanical means, each element consisting of a sheet of platinum placed between two vertical plates of zinc, as in Groves' Battery.* There is, however, only a single liquid, viz: diluted sulphuric acid. The elements have much the same form as in Wollaston's Battery. The hydrogen is prevented from adhering to the platinum plate by covering this plate with a deposit of finely divided platinum. Thus the surface is rendered rough, and the disengagement of the hydrogen much facilitated, the resistance of the couple of plates being in consequence diminished. Silver coated with a deposit of finely divided platinum is often substituted for the platinum plate, since it is cheaper.

WALKER'S BATTERY

Resembles Smee's Battery, but the electro-negative plate is of graphite or platinised graphite. The exciting agent is diluted sulphuric acid. This battery has considerable electromotive force.

WOLLASTON'S BATTERY

Is an improved form of the Crown of Cups, and is so arranged, that the action of the battery can be stopped when the current is no longer required. It consists of a number of cells, or glass vessels, united in two parallel series, in which are immersed plates of zinc and copper. The zinc plates consist of thickly rolled metal, and are generally about eight inches in length by six in breadth. The copper plates are of thin sheet, and are so bent as to surround the zinc plates without touching them. The contact is prevented by small pieces of cork. A narrow strip of copper is soldered to each copper plate, and is bent twice at right angles and soldered to the zinc plate. The first zinc plate is surrounded by the first copper plate. These two constitute a couple, each couple being immersed in the glass vessel containing acidulated water. The copper plate is soldered to the second zinc plate by a narrow strip of copper, and this zinc plate is again surrounded by a second copper plate, and so on.

---

* Page 81.

All the couples are fixed to a cross wooden frame, so that they may be covered or raised at will. The couples are lifted out of the fluid when the battery is not required.

The water is generally acidulated with $\frac{1}{20}$ of nitric acid, or $\frac{1}{15}$ of sulphuric acid.

HARE'S DEFLAGRATOR

Consists of two large copper and zinc sheets rolled together in a spiral, but protected from direct contact by horsehair or leather. The whole is immersed in a vessel containing acidulated water, and the two plates are connected by a conducting wire placed outside the liquid.

CONSTANT BATTERIES.

The energy of a single liquid battery quickly fails when it has been at work a short time, since the hydrogen liberated by the chemical action of the battery collects on the surface of the platinum (negative) plates.

Batteries are termed constant in which this result is prevented by the absorption of the hydrogen by means of strong nitric acid, solution of sulphate of copper, or other suitable agents.

DANIELL'S BATTERY

Consists of a glass or porcelain vessel containing a saturated solution of copper-sulphate, in which is immersed a copper cylinder open at both ends and perforated with holes; at the top of the cylinder is an annular shelf perforated with small holes, and placed below the level of the solution, intended to support crystals of copper-sulphate. To replace the amount of that salt decomposed as electrical action goes on, within the cylinder is a thin porous vessed of unglazed earthenware, containing water or a solution of common salt, or diluted sulphuric acid, in which is placed a cylinder of amalgamated zinc. Two thin strips of copper are fixed by binding screws to the zinc and copper cylinders, and serve to connect the elements in series.

Upon closing a Daniell's arrangement, the hydrogen formed by the action of the diluted sulphuric acid on the zinc is set free upon the surface of the copper plate, but comes in contact there with the copper-sulphate, which is reduced, sulphuric acid and metallic copper being formed, the latter being deposited upon the surface of the copper plate. Thus the sulphate of copper in solution is taken up, and should it be all consumed the hydrogen would be deposited on the copper and the constancy of the current be lost; but this is obviated by the sulphate of copper crystals, which ensure the saturation of the solution. The porous cylinder is permeated by the sulphuric acid formed by the decomposition of the sulphate, and thus the acid used up by the action on the zinc is in a measure replaced. The amount of sulphuric acid formed in the sulphate of copper solution is regular and proportional to the acid employed in dissolving the zinc, and the action of the acid on the zinc being also regular, a continuous current is consequently established.

To form a battery several of these elements are connected together, as follows:

The zinc of one is joined by a copper strip or wire with the copper of the next, and so on, from one element to another.

GROVE'S BATTERY.

In this battery nitric acid is used instead of a solution of sulphate of copper, and platinum instead of copper. It consists of a glass or porcelain vessel partly filled with diluted sulphuric acid, in which is placed a cylinder of zinc open at both ends, internal to which is a vessel of porous pipeclay containing nitric acid, on which is placed a plate of platinum bent in the form of an S. The platinum plate is provided with a binding screw, and the zinc by a similar binding screw.

In this battery the hydrogen disengaged on the platinum meets the nitric acid, and by decomposing it forms hyponitrous acid, which is disengaged as nitrous fumes.

It is the most powerful and most convenient of the two-fluid batteries, but is very expensive from the price of platinum, which becomes brittle after a time and breaks easily.

BUNSEN'S BATTERY, OR ZINC CARBON BATTERY,

Is merely a Grove's Battery in which a cylinder of carbon replaces the sheet of platinum.

The carbon employed is made either of graphitoidal carbon deposited in gas retorts, or by calcining in an iron mould an intimate mixture of coke and bituminous coal finely powdered and strongly compressed. Each element consists of the following parts: An outer vessel of glass or stoneware containing diluted sulphuric acid, in which is placed a hollow cylinder of amalgamated zinc, slit on one side from top to bottom, and containing in its turn a porous vessel holding ordinary nitric acid. In this last fluid is placed the carbon. A binding-screw is attached to the carbon, a copper wire forming the positive pole. A similar screw and wire are attached to the zinc, thus forming the negative pole.

A battery is formed of the elements by joining each carbon cylinder to the succeeding zinc cylinder by means of clamps and a strip of copper. The copper is pressed at one end between the carbon and the clamp, and at the other end it is soldered to the clamp which is fitted on the zinc of the following element, and so on. The clamp of the first carbon and that of the last zinc cylinder are alone provided with binding-screws, to which are attached the wires.

The chemical action of this battery is the same as Grove's, and it is equally powerful and less costly. It is, however, more expensive to work, although the first cost is less, and it is not so convenient to manipulate.

CALLAN'S BATTERY

Is a modified form of Grove's. Zinc and platinised lead are used in the place of zinc and platinum, and instead of pure nitric acid, this inventor used a mixture of sulphuric acid, nitric acid, and a saturated solution of nitrate of potash.

It is a much cheaper battery than Grove's, and is said to be equal to it in action.

RECENT BATTERIES.

M. MARIÉ DAVY'S BATTERY

Is a zinc carbon arrangement, but smaller in dimensions than those arrangements usually are. In the outer vessel ordinary water or brine is placed, in the porous vessel sulphate of mercury. The salt is shaken with about three times its volume of water, in which it only dissolves with difficulty, and the liquid is poured off from the pasty mass. The carbon being placed in the porous vessel the spaces become filled with the residue, and then the decanted liquid is poured into it. It is only when the pile is closed that chemical action occurs. The water is decomposed by the zinc, hydrogen being set free, and this gas, traversing the porous vessel, reduces the sulphate of mercury, forming metallic mercury, which falls to the bottom of the vessel, the sulphuric acid formed meanwhile traversing the diaphragm to act upon the zinc and intensify the action. The deposited mercury may be employed for preparing a quantity of the sulphate equal to that consumed. A little of the sulphate of mercury solution may also pass through the diaphragm, but this is rather an advantage, as its effect is to amalgamate the zinc.

This element's electro-motive force is about a quarter greater than that of Daniell's, but it has greater resistance. If continuously worked it is rapidly exhausted, but it is apparently well suited for discontinuous work, as with alarums and with the telegraph.

GRAVITY BATTERIES.

Porous vessels are open to objection, especially those of the Daniell's Battery, in which these vessels become gradually encrusted with copper, and are thus destroyed. A variety of battery has been invented in which the porous vessel is done away with, and the fluids separated by the difference of density.

M. CALLAUD'S (OF NANTES) BATTERY

Consists of a glass or earthenware vessel, in which is placed a copper plate soldered to a wire insulated by gutta-percha. Upon the plate is a layer of copper-sulphate crystals. The whole vessel is then filled with water, and a zinc cylinder is immersed in it. Thus the lower portion of the liquid is saturated with copper-sulphate. In action the battery is similar to Daniell's. The sulphate of zinc forming gradually floats on the copper-sulphate solution, in consequence of its lower density.

The manipulation of this battery is easy, the copper-sulphate consumed is not expensive, and if it is not shaken, will work continually for months, care being taken to replace the water lost by evaporation.

MINOTTO'S BATTERY.

This is a Daniell's element, the porous vessel being replaced by a layer of sand or sawdust. It consists of an earthenware vessel, at the bottom of which is placed a layer of coarsely-powdered copper-sulphate, upon which layer is placed a copper plate having an insulated copper wire. Upon this plate is a layer of sawdust or sand, and the whole is then filled with water, in which a zinc cylinder rests. In action it is like Daniell's.

The mixture of the liquids is prevented by the sawdust, which offers great resistance, increasing with its thickness. This battery is very simple and economical, and is easily constructed.

LECLANCHE'S ELEMENT.

Here a rod of carbon is placed in a porous pot, and tightly packed with a mixture of black oxide of manganese and coke. Surrounding the whole is an outer vessel containing zinc, the electro-positive element. Chloride of ammonium solution is the exciting liquid. It is desirable not to fill the vessel more than ⅓rd with the liquid. The electro-motive force of this battery is about $\frac{8}{10}$ that of a Daniell's.

ELECTRO-MOTIVE FORCE OF DIFFERENT ELEMENTS.*

The following table shows the electro-motive force of some of the arrangements most in use compared with that of an ordinary Daniell's cell charged as previously described:

Daniell's element set up with water - - - -		1·00
,, ,,	pure zinc and pure water, with pure copper and pure saturated solution of sulphate of copper - -	1·02

---

* "Ganot's Physics," by Atkinson.

Leclanche's	element:	zinc in saturated solution of chloride of ammonium	1·32
Marié Davy's	,,	- - - - - - -	1·41
Bunsen's	,,	carbon in nitric acid	1·77
,,	,,	carbon in chromic acid	1·87
Groves'	,,	platinum in nitric acid	1·82

RULES AND EXAMPLES FOR THE SOLUTION OF QUESTIONS involving

(a) The determination of the percentage composition of a compound from the chemical formula.

(b) The determination of a chemical formula of the compound from the percentage composition.

A. The formula of a compound being given, to ascertain the percentage composition, and thence the amount of the several constituents in any given quantity of the compound.

Rule.—Add together the atomic weights of the several constituents, and in this manner obtain the molecular weight of the compound; then, as the molecular weight of the whole compound is to 100, so is the weight of each constituent to the percentage quantity of that constituent, thus:—

Example 1. Sulphuric Acid = H_2SO_4

$$\begin{array}{rcl} 2H & = & 2 \\ S & = & 32 \\ 4O & = & 64 \\ \hline H_2SO_4 & = & 98 \end{array}$$

Then to ascertain the quantity of oxygen (O) in 100 parts of H_2SO_4.

$$98 : 100 :: 64 : x$$

$$\therefore x \text{ (the quantity of O required)} = \frac{100 \times 64}{98} = 65{\cdot}306$$

Since 100 × 64 = 6400; and 6400 + 98 =

$$\begin{array}{r|l|l} 98 & 6400 & 65{\cdot}306 \\ & \underline{588} & \\ & \;\;520 & \\ & \;\;\underline{490} & \\ & \;\;\;\;300 & \\ & \;\;\;\;\underline{294} & \\ & \;\;\;\;\;\;600 & \\ & \;\;\;\;\;\;\underline{588} & \\ & \;\;\;\;\;\;\;\;12 & \end{array}$$

65·306 oxygen.

Or by the Unity Method—

If 98 (the sum of the atomic weights) yield 64 parts of oxygen

$$\therefore \quad 1 = \frac{64}{98}$$

$$\therefore 100 = \frac{64}{98} \times 100 = 65{\cdot}306 \text{ of oxygen.}$$

Now if we require to find the quantity of O necessary to make 1 ton of sulphuric acid—

$$\text{as—} \quad \overset{\text{tons}}{100} : \overset{\text{ton}}{1} :: 65{\cdot}306 : x$$

$$\therefore x = \frac{1 \times 65{\cdot}306}{100} = \overset{\text{tons}}{{\cdot}65306} = \overset{\text{cwt.}}{13}\;\; \overset{\text{qrs.}}{0}\;\; \overset{\text{lb.}}{6{\cdot}85440}$$

Ex. 2. The formula of a certain salt is NH_4Cl. How is the percentage composition of each of its constituents found?

Nitrogen (N) = 14
Hydrogen $(H)_4$ = 4
Chlorine (Cl) = 35·5

The whole compound NH_4Cl = 53·5

(a) $\therefore$ 53·5 : 100 :: 14 (N) : x (N)

$$\therefore x = \frac{100 \times 14}{53{\cdot}5} = \frac{1400}{53{\cdot}5} = 26 \text{ nearly.}$$

Or (Unity Method)—

If 53·5 parts yield 14 of nitrogen

$$\therefore \quad 1 = \frac{14}{53.5}$$

$$\therefore 100 = \frac{14}{53{\cdot}5} \times 100 = \frac{1400}{53{\cdot}5} = 26 \text{ (N) nearly.}$$

(b) $$\therefore\ 53\cdot5 : 100 :: 4\ (\mathrm{H}) : x\ (\mathrm{H})$$

$$\therefore\ x = \frac{100 \times 4}{53.5} = \frac{400}{53\cdot5} = 7\cdot476\ (\mathrm{H})\ \text{nearly.}$$

Or by Unity—

If 53·5 yield 4 (H)

$$\therefore\quad 1 = \frac{4}{53\cdot5}$$

$$\therefore\ 100 = \frac{4}{53\cdot5} \times 100 = \frac{400}{53\cdot5} = 7\cdot476\ (\mathrm{H})\ \text{nearly.}$$

(c) $$\therefore\ 53\cdot5 : 100 :: 35\cdot5\ (\mathrm{Cl}) : x\ (\mathrm{Cl})$$

$$\therefore\ x = \frac{100 \times 35\cdot5}{53\cdot5} = \frac{710}{10\cdot7} = 66\cdot355\ (\mathrm{Cl})$$

Or by Unity—

If 53·5 yield 35·5 Cl,

$$\therefore\quad 1 = \frac{35\cdot5}{53\cdot5}$$

$$\therefore\ 100 = \frac{35\cdot5}{53\cdot5} \times 100 = \frac{710}{10\cdot7} = 66\cdot355\ (\mathrm{Cl})$$

Ex. 3. Nitric acid has the formula HNO_3.

Find the composition of nitric acid in 100 parts (H=1, N=14, O=16).

The molecular weight of nitric acid = 1 + 14 + 48 = 63.

(a) $\therefore$ 63 (parts) : 100 (parts) :: 1 (H) : x (H).

$$\therefore\ x\ (\text{amount of H}) = \frac{100}{63} = 1\cdot59\ (\mathrm{H})\ \text{nearly.}$$

Or by Unity—

If 63 yield 1,

$$\therefore\quad 1 = \frac{1}{63}$$

$$\therefore\ 100 = \frac{1}{63} + 100 = \frac{100}{63} = 1\cdot59\ (\mathrm{H})\ \text{nearly.}$$

(b) $\therefore$ 63 : 100 :: 14 (N) : x (N).

$$x\ (\text{amount of N}) = \frac{100 \times 14}{63} = \frac{1400}{63} = 22\cdot22\ (\mathrm{N})\ \text{nearly.}$$

Or by Unity—

If 63 yield 14

$$\therefore\quad 1 = \frac{14}{63}$$

$$\therefore\ 100 = \frac{14}{63} \times 100 = \frac{1400}{63} = 22\cdot22\ (\mathrm{N})\ \text{nearly.}$$

(c) $\therefore$ 63 : 100 :: 48 (O) : x (O).

$$\therefore x \text{ (amount of O)} = \frac{100 \times 48}{65} = \frac{4800}{65} = 76{\cdot}19 \text{ (O)}.$$

Or by Unity—

If 63 yield 48

$$\therefore \quad 1 = \frac{48}{63}$$

$$\therefore 100 = \frac{48}{63} \times 100 = \frac{4800}{63} = 76{\cdot}19 \text{ (O)}.$$

$\therefore$ The following is the percentage composition of the whole HNO_3, viz. :

Hydrogen,	1·59
Nitrogen,	22·22
Oxygen,	79·19

Ex. 4. The following equations represent the manufacture of nitric acid, viz. :

(a)	Nitrate of potash $2KNO_3$	Sulphuric acid $+ H_2SO_4$	Nitrate of potash $= KNO_3$	Hydrogen potassic sulphate $+ HKSO_4$	Nitric acid HNO_3
(b)	Hydric potassic sulphate $HKSO_4$	Nitrate of potash $+ KNO_3$	Neutral potassic sulphate $= K_2SO_4$	Nitric acid $+ HNO_3$	

What amounts of H_2SO_4 (sulphuric acid) and KNO_3 (nitrate of potash) are needed to produce 1 lb. of HNO_3 (nitric acid)?

It is evident from the above equations that for every *two* parts of nitrate of potash and one part of sulphuric acid used, *two* parts of nitric acid result. Now the

Molecular weight of (KNO_3) nitrate of potash = 101

$$\begin{aligned} \text{Since } K &= 39 \\ N &= 14 \\ O_3 &= 48 \\ &\overline{101} \end{aligned}$$

Molecular weight of (H_2SO_4) Sulphuric acid = 98

" " (HNO_3) Nitric acid = 63

$\therefore$ 126 ($(HNO_3)_2$) : 1 (lb. of HNO_3) :: 202 ($(KNO_3)_2$) : x

And x (weight of KNO_3 needed) =

$$\frac{202}{126} = \frac{101}{63} = 1{\cdot}603 \text{ lb.}$$

Again—

$$126\ ((HNO_3)_2) : 1\ (\text{lb. of } HNO_3) :: 98\ (H_2SO_4) : x$$

$$\therefore x\ (\text{weight of sulphuric acid required}) =$$

$$\frac{98}{126} = \frac{7}{9} = \cdot 7 \text{ lb.}$$

B. Conversely. To ascertain the empirical formula of a compound from its percentage composition, the following process is adopted.

Rule.—Divide the amount of each element by its atomic weight; then divide each of the resulting quotients by their common measure. The quotients which result from this second division will give the number of atoms of each element entering into the compound, and must consequently give its formula.

Example 1. The following is found to be the percentage composition of a compound—

Carbon - - -	27·27
Oxygen - -	72·73

Ascertain its formula (C = 12, O = 16).

27·27 ÷ 12 (the atomic weight of C) = 2·2725. Thus—

12) 27·27 (2·2725
24
——
32
24
——
87
84
——
30
24
——
60
60
——

2·2725 Carbon.

And 72·73 ÷ 16 (the atomic weight of O) = 4·5456. Thus—

```
16 ) 72·73 ( 4·5456
     64
     ——
      87
      80
      ——
       73
       64          4·5456 Oxygen.
       ——
        90
        80
        ——
        100
         96
        ———
          4*
```

The common measure of 2·2725 and 4·5456 is 2·2725.

$$\text{Dividing} \therefore \frac{2·2725}{2·2725} = 1 \text{ C}$$

And

$$\frac{4·5456}{2·2725} = 2 \text{ O}.$$

∴ the formula of the compound is CO_2 (Carbonic Anhydride).

Ex. 2. What formula must be given to a salt, the composition of which is as follows?—

Potassium - -	31·837
Chlorine - -	29·000
Oxygen - -	39·183

31·837 ÷ 39, (atomic weight of Potassium) = ·816 (K) nearly.

29·000 ÷ 35·5 (,, ,, ,, Chlorine) = ·816 (Cl) nearly.

39·183 ÷ 16 (,, ,, ,, Oxygen) = 2·45 (O) nearly.

∴ ·816 (K) : ·816 (Cl) :: 2·45 (O) :: 1 : 1 : 3.

∴ The formula = $KClO_3$ (Potassium Chlorate).

---

* It is a matter of the utmost difficulty to *exactly* determine the quantitative composition of a compound, and this will account for the slight inaccuracy of the above division.

TABLES OF ANALYSIS

FOR THE

COMMONER METALS AND ACIDS.

EXPLANATORY TABLE OF THE SYMBOLS EMPLOYED IN THE FOLLOWING TABLES OF ANALYSIS.

Ag	Argentum	Silver.
$AgNO_3$	Argenti Nitras	Nitrate of Silver.
Al	Aluminium	Aluminium.
As	Arsenicum	Arsenic.
As_2O_3	Arseniosum Anhydridum	Arsenious Anhydride.
As_2O_5	Arsenicum Anhydridum	Arsenic Anhydride.
Ba	Barium	Barium.
$BaCl_2$	Barii Chloridum	Chloride of Barium.
Bi	Bismuthum	Bismuth.
Ca	Calcium	Calcium.
$CaCl_2$	Calcii Chloridum	Chloride of Calcium.
Cd	Cadmium	Cadmium.
Co	Cobaltium	Cobalt.
$Co(NO_3)_2$	Cobaltii Nitras	Nitrate of Cobalt.
CO_2	Carbonicum Anhydridum	Carbonic Anhydride.
Cu	Cuprum	Copper.
Fe	Ferrum	Iron.
Fe_2Cl_6	Ferri Perchloridum	Perchloride of Iron.
Fe_2O_3	Ferri Peroxidum	Peroxide of Iron.
$FeSO_4$	Ferri Sulphas	Sulphate of Iron.
HCl	Acidum Hydrochloricum	Hydrochloric Acid.
$HC_2H_3O_2$	Acidum Aceticum	Acetic Acid.
Hg	Hydrargyrum	Mercury.
HNO_3	Acidum Nitricum	Nitric Acid.
H_2O	Aqua	Water.
H_2S	Acidum Hydrosulphuricum	Hydrosulphuric Acid or Sulphuretted Hydrogen.
H_2SO_4	Acidum Sulphuricum	Sulphuric Acid.
K	Kalium	Potassium.
K_2CO_3	Potassæ Carbonas	Carbonate of Potash.

K_2CrO_4	Potassæ Chromas	Chromate of Potash.
KCy	Potassii Cyanidum	Cyanide of Potassium.
KHO	Liquor Potassæ	Solution of Potash.
$K_2H_2Sb_2O_7$	Potassæ Antimonias	Antimoniate of Potash.
KNO_3	Potassæ Nitras	Nitrate of Potash.
L	Lithium	Lithium.
Mg	Magnesium	Magnesium.
Mn	Manganesium	Manganese.
Na	Natrium	Sodium.
Na_2CO_3	Sodæ Carbonas	Carbonate of Soda.
Na_2HPO_4	Sodæ Phosphas	Phosphate of Soda.
$NaNH_4HPO_4$	Sodium Ammonium Hydrogen Phosphate	Microcosmic Salt.
NH_3	Ammonia	Ammonia.
NH_4Cl	Ammonii Chloridum	Chloride of Ammonium.
$(NH_4)_2CO_3$	Ammoniæ Carbonas	Carbonate of Ammonia.
$(NH_4)_2C_2O_4$	Ammoniæ Oxalas	Oxalate of Ammonia.
NH_4HO	Liquor Ammoniæ	Solution of Ammonia.
NH_4HS	Ammonii Sulphidum	Sulphide of Ammonium.
$(NH_4)_2HAsO_4$	Ammoniæ Arsenias	Arseniate of Ammonia.
Ni	Nickelium	Nickel.
Pb	Plumbum	Lead.
PbO_2	Plumbi Peroxidum	Peroxide of Lead (Puce-coloured).
Pb_3O_4	Minium	Red Lead.
$PtCl_4$	Platini Perchloridum	Perchloride of Platinum
Sb	Stibium	Antimony.
SbH_3	Antimonii Hydridum	Antimoniuretted Hydrogen.
Sn	Stannum	Tin.
SO_2	Sulphurosum Anhydridum	Sulphurous Anhydride
Sr	Strontium	Strontium.
Zn	Zincum	Zinc.

Before applying the confirmatory tests alluded to in the following tables, the precipitate should be dissolved, if possible, in a suitable solvent.

PRELIMINARY EXAMINATION.

If the substance be a solid, observe whether it is
1. Soluble or insoluble in water.
2. If it be colourless or coloured.
3. Whether alkaline, acid, or neutral to test paper.
4. Add Na_2CO_3. Heat if no precipitate is occasioned in the cold.

If no precipitate falls even upon heating, it is evident that all those metals are absent the carbonates of which are insoluble.

5. Heat on Platinum foil; in dealing with a very diluted solution, it should be heated in a test tube.
   - *a.* Is it completely volatile without residue or volatile with residue; possibly salts of Hg, NH_3, As_2O_3, As_2O_5, chlorides of Sb, Sn, etc.
   - *b.* Visibly decomposed with residue; several organic salts, those of the alkalies and alkaline earths, leave an ash which is alkaline to test paper, and upon the addition of HCl effervesces.
   - *c.* Leaving carbonaceous residue burning to CO_2. This is the case with certain organic acids.
   - *d.* Giving colour to flame: Potassium is violet; Sodium, yellow; Lithium, scarlet; Barium, light-green; Strontium, crimson; Calcium, yellow; Free Phosphoric and Boracic Acids, green; Copper, green; Cupric Chloride, blue; Salts of Lead, Arsenic, and Antimony, blue, etc.
   - *e.* Fuse on Platinum foil (almost all the salts of the alkalies and of the alkaline earths).

Add to residue H_2SO_4 and again heat; if phosphates or borates are present they will give a green colour to flame.

6. Deflagrate on charcoal (nitrates, chlorates, bromates, and iodates).

It may be necessary to examine the volatilised substance.

If the substance be solid, transfer it to a narrow glass tube open at both ends, or to a narrow test tube and heat it.

If the substance be insoluble in water add HCl; if still not entirely soluble add HNO_3. Should the whole be insoluble in the mixed acids ($HCl + HNO_3$), fuse it with four times its weight of a mixture of K_2CO_3 and Na_2CO_3.

If a solution of a salt contains one base, the test re-agents should be applied in the following order :—

Test papers — Na_2CO_3, HCl, HCl + H_2S, NH_4HS, $(NH_4)_2CO_3$ + NH_4Cl, $NaNH_4HPO_4$, KHO, and lastly $PtCl_4$ + HCl.

For finding the acid in a salt, the chief tests are HCl. HCl + H_2S. $BaCl_2$, subsequently adding HNO_3. $AgNO_3$, subsequently adding HNO_3 and NH_4HO to the precipitate carefully washed.

In testing for nitrates the acid should be set free by H_2SO_4, and the characteristic tests applied, viz., metallic Cu and $FeSO_4$.

TABLES OF ANALYSIS FOR THE COMMONER METALS IN SOLUTION.

GROUP I. Add HCl.

Precipitate (Ppt). (Preserve filtrate for Group II).

Hg as Mercurous Salt. Pb.* Ag (as Chlorides).

Wash, boil with much water, and filter.

<table>
<tr><td colspan="2">Precipitate
Hg (mercurous salt). Ag.
Wash, add NH_4HO.</td><td rowspan="2">Filtrate
Pb.
add H_2SO_4.
White Ppt.
For confirmatory tests, see page 39.
Pb must also be sought for in Group II by H_2S, since in a weak solution of a Pb salt HCl may cause no precipitate.</td></tr>
<tr><td>Precipitate
Hg (ous).
Black.
See tests, page 44.</td><td>Filtrate
Ag,
add HNO_3.
White Ppt.
See tests, page 46.</td></tr>
</table>

N.B.—The HCl precipitate may include some salt of Bismuth, Antimony, or Arsenic; these are, however, readily dissolved by excess of the acid.

* The Pb precipitate is unchanged by NH_4HO.

GROUP II. H_2S.

Through the filtrate from Group I. pass H_2S and filter.

<table>
<tr><td colspan="8">Precipitate. [Preserve filtrate for Group III.]
Cd, Cu, Hg (mercuric salt), Pb, Bi, As, Sb, Sn (as Sulphides).
Collect, wash, add NH_4HS and filter.</td></tr>
<tr><td colspan="5">Precipitate
Cd, Cu, Hg (ic) Pb, Bi.
Wash, boil with HNO_3, and filter.</td><td colspan="3">Filtrate
As, Sb, Sn,
add dil. HCl, filter, drain well, add strong HCl, boil, slightly dilute and filter.</td></tr>
<tr><td rowspan="3">Precipitate
Hg (ic)
Black.
Dissolve in HNO_3.
Tests, page 44.</td><td colspan="4">Filtrate
Cd, Cu, Pb, Bi,
add NH_4HO, and filter.</td><td rowspan="3">Insoluble
As.
Yellow.
For tests, see Part I, pages 55, 56.</td><td colspan="2">Filtrate
Sn, Sb.
Place in a Hydrogen apparatus.</td></tr>
<tr><td colspan="2">Precipitate
Pb, Bi.
Wash, add a few drops of HNO_3, dilute, filter.</td><td colspan="2">Filtrate
Cd, Cu,
add KCy and H_2S.</td><td rowspan="2">Sb
comes off as SbH_3.
Tests, page 36.</td><td rowspan="2">Sn
remains on the zinc.
Dissolve in HCl.
Tests, page 31.</td></tr>
<tr><td>Precipitate
Bi.
Tests, page 37.</td><td>Filtrate
Pb,
add H_2SO_4, let stand.
White Ppt.
Tests, page 39.</td><td>Precipitate
Cd.
Yellow, insoluble in alkalies.</td><td>Filtrate
Cu,
add $HC_2H_3O_2$.
Brown Ppt.
Tests, page 42.</td></tr>
</table>

N.B.—If the sulphuretted hydrogen precipitate be white it is only sulphur. Care must be taken that the H_2S be passed through the liquid until saturation, since if lead or mercury is present, insufficient H_2S may produce a peculiar oxy-sulphide or hydrato-sulphide of these metals.

GROUP III.

To the filtrate from Group II. add NH_4Cl, NH_4HO and NH_4HS.
Gently warm and filter.

<table>
<tr><td colspan="7">Precipitate. [Preserve filtrate for Group IV.]
Zn, Mn, Co, Ni, Al, Fe, Cr (as Oxides).
Collect, wash, dissolve in HCl, with a few drops of HNO_3, boil, add NH_4HO, stir, filter.</td></tr>
<tr><td colspan="3">Precipitate
Fe, Al, Cr, Mn ?*
Wash, dry, fuse on platinum foil with Na_2CO_3 and KNO_3 ; boil with water and filter.</td><td colspan="4">Filtrate
Zn, Mn, Co, Ni.
Add $HC_2H_3O_2$. Pass H_2S through solution and filter.</td></tr>
<tr><td rowspan="3">Residue
Fe_2O_3.
Reddish-brown.
Test for ferrous or ferric salt in original soln.
Tests, page 30.</td><td colspan="2">Filtrate.
If yellow, Cr. Divide into two portions.</td><td rowspan="3">Solution
Mn.
Add NH_4HO and NH_4HS.
Pink turning Brown.
Look for Mn in the Fe, Al, Cr, Ppt.
Tests, pages 25, 26.</td><td colspan="3">Precipitate
Zn, Co, Ni.
Boil with HCl, and a little HNO_3 ; add KHO, and filter.</td></tr>
<tr><td rowspan="2">Solution
Al.
Add NH_4HO, warm and filter.
White Ppt.
Tests, page 20.</td><td rowspan="2">Solution
Cr.
Add $HC_2H_3O_2$ and $AgNO_3$ in excess.
Red Ppt.
Or boil with H_2SO_4 and spirit.
Green solution.
Tests, pages 32, 33.</td><td colspan="2">Precipitate
Co, Ni.
Dissolve in excess of HCl and add KCy and excess of KHO.</td><td rowspan="2">Filtrate
Zn.
Add NH_4HS
White Ppt.
Tests, page 23.</td></tr>
<tr><td>Ppt.
Ni.
Pale Apple-green.
Tests, page 31.</td><td>Filtrate
Co.
Evaporate to dryness and test residue with borax bead, red-brown in outer flame, grey in inner.
Tests, page 31.</td></tr>
</table>

* Mn may be tested for by adding dil. HNO_3, and either PbO_2 or Pb_3O_4 to the solution and then boiling ; a red tint is due to permanganic acid.

GROUP IV.

To the filtrate from Group III. add $(NH_4)_2CO_3$.

Warm and filter.

Precipitate Ba, Sr, Ca	[Preserve filtrate for Group V.] (as Carbonates).

Collect, wash, dissolve in $HC_2H_3O_2$, add excess of K_2CrO_4 and filter.

<table>
<tr><td rowspan="2">Precipitate
Ba.
Yellow.
Tests, page 18.</td><td colspan="2">Filtrate
Sr, Ca.
Add very diluted H_2SO_4; let stand and filter.</td></tr>
<tr><td>Ppt.
Sr.
White.
Tests, page 16.</td><td>Filtrate
Ca.
Add $(NH_4)_2C_2O_4$.
White Ppt.
Tests, pages 15, 16.</td></tr>
</table>

GROUP V.

To the filtrate from Group IV. add $(NH_4)_2HAsO_4$ or Na_2HPO_4.

Stir and filter.

<table>
<tr>
<td rowspan="2">Precipitate
Mg, (as ammonio-magnesian-arseniate (NH_4MgAsO_4) or sodio-magnesian-phosphate ($NaMgPO_4$)).
White.
Heated before blow pipe with $Co(NO_3)_2$ acquires a pink tinge.
Tests, page 22.</td>
<td colspan="2">Filtrate
L, K, Na, NH_3.
Evaporate to a small bulk and add NH_4HO.</td>
</tr>
<tr>
<td>Precipitate
L.
Scarlet on platinum, in inner flame, gives to outer flame a purple colour.</td>
<td>Filtrate
K, Na, NH_3.
Evaporate, ignite, and dissolve in water.
Na by the yellow flame; and by the white ppt. with $K_2H_2Sb_2O_7$ (page 9);
K by yellow ppt. with $PtCl_4$ (page 7);
NH_3 must be sought for in the original solution.
Tests, page 10, and Part I., page 16.</td>
</tr>
</table>

TABLES OF ANALYSIS FOR THE COMMONER ACIDS.

Precipitated by $AgNO_3$.	Precipitated by Fe_2Cl_6.	Precipitated by $BaCl_2$,	Precipitated by $CaCl_2$.	Decomposed by H_2SO_4.	Not precipitated.
Chlorides, white Bromides ,, Cyanides ,, Borates ,, Sulphites ,, Carbonates ,, Hyposulphites ,, Oxalates ,, Tartrates ,, Citrates ,, Chromates, crimson Iodides, yellow Phosphates ,, Sulphides, black Iodates, white The Silver Chloride, Bromide, Iodide, Cyanide and Sulphide are insoluble in dil. HNO_3. The others are soluble.	Borates, yellowish. Carbonates, reddish. Oxalates, yellow. Phosphates, yellowish-white. Sulphides, black. Acetates in neutral solution, cherry-red colour.	Borates, white Carbonates ,, Citrates ,, Oxalates ,, Phosphates ,, Sulphites ,, Sulphates ,, Tartrates ,, All soluble in HCl, except the Sulphate of Barium. The Citrate and Tartrate of Barium char when heated on platinum foil. The Sulphite and Carbonate of Barium are decomposed by acids with effervescence.	Borates. Phosphates. Carbonates. Sulphates. Citrates. Sulphites. Oxalates. Tartrates. The Borate, Carbonate and Citrate are dissolved by solution of NH_4Cl; the Sulphate alone is soluble in much H_2O. All are soluble in HCl, except much sulphate. All are soluble in $HC_2H_3O_2$, except oxalate and some tartrate and sulphate. The dry Citrate and Tartrate char when heated. With acids, the Carbonate and Sulphite effervesce.	Acetates, the odour of $HC_2H_3O_2$ being produced on warming the solution. Carbonates, with effervescence from the evolution of H_2S, SO_2 and CO_2 gases, known by their odour. Cyanides, the odour of HCy being produced. Sulphides. Sulphites.	Chlorates. Nitrates. All Chlorates are soluble, and deflagrate on charcoal; heated on platinum they are converted into chlorides; with HCl they are changed in colour to a yellowish-green, evolving Cl. The Nitrates are all soluble, deflagrate on charcoal, and are changed by red heat into Nitrites.

ACETATES.

These are usually colourless and soluble. The acetates of the fixed alkalies and alkaline earths are converted by heat into carbonates without blackening.

$AgNO_3$, in strong solution, produces a white precipitate of Acetate of Silver ($AgC_2H_3O_2$), soluble in NH_3 and HNO_3.

Fe_2Cl_6 gives a cherry-red colour.

H_2SO_4 and Alcohol (C_2H_6O), by heat, give off Acetic Ether ($C_2H_5,C_2H_3O_2$).

Free Acetic Acid, $HC_2H_3O_2$, has an odour of vinegar.

BROMIDES.

Very like Chlorides; they are decomposed by Chlorine with the orange colour of Bromine.

$AgNO_3$ gives a yellowish-white precipitate of Bromide of Silver ($AgBr$), soluble in excess of NH_3, but insoluble in HNO_3.

BORATES.

The alkaline Borates are soluble and fusible. The insoluble Borates are dissolved by ammoniacal salts and by acids.

Chief salt is Borax ($Na_2B_4O_7$). $BaCl_2$ gives a white precipitate of Meta-Borate of Barium ($Ba(BO_2)_2$).

$AgNO_3$ gives a white Meta-Borate of Silver ($AgBO_2$).

Borates also give a green colour to flame.

CARBONATES.

The alkaline Carbonates are soluble. Heat converts the bicarbonates of the alkaline earths into carbonates with evolution of CO_2.

HCl causes effervescence. Liquor Calcis (CaH_2O_2) gives a white precipitate of Carbonate of Lime ($CaCO_3$).

$BaCl_2$ gives a white precipitate of Carbonate of Barium ($BaCO_3$).

$AgNO_3$ gives a white precipitate of Carbonate of Silver (Ag_2CO_3).

CHLORATES.

All soluble. Chief salt is Chlorate of Potash ($KClO_3$). They deflagrate on charcoal. Heated on platinum they are converted into Chlorides, and tested for as such.

HCl, on **heating,** changes the colour of chlorates to *yellowish-green,* yielding Cl and Chlorine Trioxide (Cl_2O_3).

CHLORIDES.

Most are colourless, soluble salts. The insoluble salts are Calomel ($HgCl$), Chloride of Silver ($AgCl$), and Chloride of Lead ($PbCl_2$).

$AgNO_3$ gives a white precipitate of $AgCl$, soluble in NH_3 and reprecipitated by HNO_3.

Manganese Dioxide (MnO_2) with H_2SO_4 yields Chlorine gas (Cl), known by its odour and colour, and by its turning starch paper blue when soaked in Iodide of Potassium (KI).

HNO_3 gives fumes of Cl and Nitroxyl Chloride ($NOCl_2$).

CITRATES.

Are alkaline, colourless and soluble. Are converted by heat into carbonates, giving out pungent fumes and liberating Carbon (C).

$AgNO_3$ gives a white precipitate of Citrate of Silver ($Ag_3C_6H_5O_7$).

$CaCl_2$ gives a white precipitate of Citrate of Lime ($Ca_32C_6H_5O_7$), insoluble in KHO, but readily soluble in NH_4Cl.

HYPOSULPHITES.

The chief salt is the Sodium Hyposulphite ($Na_2S_2O_3$), soluble and alkaline.

HCl precipitates Sulphur (S), the solution becoming yellowish-white, and liberating SO_2.

$BaCl_2$ gives a white precipitate of Hyposulphite of Barium (BaS_2O_3).

$AgNO_3$ gives a white precipitate of Hyposulphite of Silver ($Ag_2S_2O_3$), which rapidly decomposes into H_2SO_4 and black Sulphide of Silver (Ag_2S).

IODIDES.

Resemble chlorides; but many are coloured. They are decomposed by Cl.

$AgNO_3$ gives a yellowish precipitate of Iodide of Silver (AgI).

Mercurous Nitrate ($HgNO_3$) gives a green precipitate of Mercurous Iodide (HgI).

Mercuric Chloride ($HgCl_2$) gives a scarlet Mercuric Iodide (HgI_2), soluble in excess.

HNO_3, sets free solid Iodine (I), by which a solution of starch is rendered blue.

By heat a violet vapour is given off.

Acetate of Lead ($Pb2C_2H_3O_2$) gives a yellow Iodide of Lead (PbI_2), soluble in excess of hot water.

NITRATES.

Colourless salts, deflagrating on charcoal. Chief salt is Nitrate of Potash (KNO_3), changed by red heat into Nitrite of Potash (KNO_2), which, with Sulphate of Copper ($CuSO_4$), forms green Nitrite of Copper ($Cu2NO_2$), and when heated with H_2SO_4 gives off fumes of Nitrogen Trioxide (N_2O_3).

H_2SO_4 liberates HNO_3 from a nitrate; with Metallic Copper (Cu) and H_2SO_4 orange vapours of Nitrogen Tetroxide (N_2O_4) are given off.

A green crystal of Sulphate of Iron ($FeSO_4$) and a drop or two of H_2SO_4 form reddish-brown pernitrate of iron (Fe_26NO_3).

OXALATES.

Decompose when heated upon platinum into carbonates with blackening, or they are reduced.

$AgNO_3$ gives a white precipitate of Oxalate of Silver ($Ag_2C_2O_4$), soluble in cold HNO_3.

$CaCl_2$ gives a white Oxalate of Lime (CaC_2O_4), insoluble in Acetic Acid ($HC_2H_3O_2$).

A dry oxalate with H_2SO_4 evolves Carbonic Oxide (CO) and CO_2.

PHOSPHATES.

The alkaline orthophosphates are soluble.

$BaCl_2$ gives a white Orthophosphate of Barium ($BaHPO_4$), soluble in HNO_3.

$AgNO_3$ gives a yellow tribasic Phosphate of Silver (Ag_3PO_4), soluble in HNO_3 and NH_3.

Sulphate of Magnesia ($MgSO_4$) with NH_4Cl and NH_3 gives a white crystalline Ammonio-Magnesian Phosphate ($NH_4MgPO_4, 6H_2O$).

For Pyrophosphates and Metaphosphates, see Part I., pages 52, 53.

SULPHATES.

All soluble except the Sulphates of Barium ($BaSO_4$), Strontium ($SrSO_4$), and Lead ($PbSO_4$). Sulphate of Lime ($CaSO_4$) is sparingly soluble.

$BaCl_2$ or Nitrate of Barium ($Ba2NO_3$) gives a white precipitate of Sulphate of Barium ($BaSO_4$), insoluble in all alkalies and acids, except boiling Sulphuric Acid.

Acetate of Lead ($Pb2C_2H_3O_2$) gives a white precipitate of Sulphate of Lead ($PbSO_4$).

By fusion with Na_2CO_3 on charcoal the Sulphide is formed.

SULPHIDES.

The alkaline Sulphides are soluble, and smell of Sulphuretted Hydrogen (H_2S).

With HCl, H_2S is evolved ; known by its odour of rotten eggs, and by blackening lead paper.

SULPHITES.

By heat HCl evolves SO_2, with odour of burning sulphur.

$AgNO_3$ gives a white Sulphite of Silver (Ag_2SO_3), reduced by heat to H_2SO_4 and Metallic Silver (Ag).

TARTRATES.

Fuse and carbonise, giving odour of burnt sugar. Chief salt, the Acid Tartrate of Potash ($KHC_4H_4O_6$). HCl precipitates the neutral Tartrate of Potash ($K_2C_4H_4O_6$) from a solution of the acid tartrate.

$AgNO_3$ gives white Tartrate of Silver ($Ag_2C_4H_4O_6$).

$CaCl_2$ gives white Tartrate of Lime ($CaC_4H_4O_6$).

FINIS OF PART II.

INDEX.

PAGE
Acid, Definition of .. 2
Acids, Tables of Analysis for 101
,, Theory of .. 67
Air Pump, The .. 70
Alabaster .. 15
Alkalies, Metals of the .. 2
,, General Characteristics of the .. 13
Alkaline Earths, Metals of the 13
,, ,, General Characteristics of the .. 18
Alloy .. 53
Aluminium .. 18
,, Chloride .. 18
,, Oxide .. 20
,, Sulphate .. 20
,, Tests .. 20
Amalgam .. 53
Ammonium .. 10
,, Bicarbonate .. 11
,, Carbonate .. 11
,, Chloride .. 10
,, Nitrate .. 11
,, Phosphate .. 11
,, Sulphate .. 11
,, Sulphide .. 12
,, Tests .. 12
Anhydrite .. 15
Antimony Group, The .. 34
,, ,, General Characteristics of the .. 37
Antimony .. 34
,, Chlorides .. 35
,, Oxides .. 35
,, Sulphides .. 35
,, Tests .. 36
Antimoniuretted Hydrogen .. 36
Appendix .. 50
Artiads .. 51
Atom .. 50
Atomic Theory .. 53
Atomic Weights .. 50

PAGE
Barium .. 16
,, Chloride .. 17
,, Oxides .. 17
,, Sulphate .. 17
,, Tests .. 18
Batteries, Electric .. 76
,, Bunsen's .. 82
,, Callaud's .. 82
,, Constant .. 80
,, Daniell's .. 80
,, Gravity .. 83
,, Grove's .. 81
,, Leclanche's .. 84
,, Marie Davy's .. 83
,, Minotto's .. 84
,, Smee's .. 79
,, Walker's .. 79
,, Wollaston's .. 79
Bell-Metal .. 39
Bessemer Process, The .. 28
Bismuth .. 36
,, Oxides .. 36
,, Tests .. 37
Black Wash .. 42
Blast Furnace, The .. 27
Bleaching Powder .. 15
Blend .. 22
Brass .. 39
Braunite .. 25
Bronze .. 39
Cadmium .. 23
,, Oxide .. 24
,, Tests .. 24
Cæsium .. 13
Calamine .. 22
Calcium .. 13
,, Carbonate .. 14
,, Chloride .. 15
,, Oxides .. 14
,, Sulphate .. 15
,, Tests .. 15
Calomel .. 43

PAGE
Cast Iron 26
Steel 26
Caustic Potash 4
Caustic Soda 8
Celestine 16
Cerusite 38
Chemical Formula, A 53
Chemical Equation, A 53
Chromium 32
,, Oxides 32
,, Tests 32
Chromates, The 32
Chromic Acid 32
Cinnabar 42
Clay-Ironstone 27
Cobalt 30
Cobalt Glance 31
Copper 39
,, Arsenite 41
,, Carbonate 41
,, Chlorides .. 40, 41
,, Nitrate 41
,, Oxides 40, 41
,, Sulphate 41
,, Sulphide 41
Compound Radicals 51
Copperas 28
Corrosive Sublimate 44
Crown of Cups, The 78
Cylindrical Electrical Machine 75
Common Plate ,, ,, 75
Density 53
Dolomite 21
Dry Pile of De Luc, The .. 79
Elba-Iron 26
Electricity 72
Electric Current 76
Electrophorus, The 76
Fast Colours 20
Felspar 18
Ferric Acid 30
Fulminating Gold 47
Galena 38
Gas, A 53
German Silver 22
Glass 20
Gold 46
,, Chlorides 47
,, Oxides 47
Gold Group, The 46
,, ,, General Characteristics of the 49
Gold-leaf Electrophorus, The 73
Gravity 53
Green Vitriol 30
Gun-Metal 39

PAGE
Gypsum 15
Hare's Deflagrator 80
Hausmannite 25
Heat 68
,, Latent 68
,, Specific 68
Horn Silver 46
Hydroxylamine 12
Insulator, The 74
Iron 26
,, Carbonate 29
,, Chlorides 29
,, Manufacture of 26
,, Oxides 28, 29, 30
,, Sulphates 28, 30
,, Sulphide 29
,, Varieties of 26
,, Tests 20
Iron Group, The 24
,, ,, General Characteristics of the 33
Iron Pyrites 26
Isomorphism 19
Laws of Chemical Combination 51
,, of Constant Proportion .. 51
,, of Multiple Proportion .. 51
,, of Reciprocal Proportion 52
Lakes 20
Lead 37
,, Acetate 38
,, Carbonate 38
,, Chloride 38
,, Chromate 39
,, Iodide 39
,, Sulphate 38
,, Tests 39
Leyden Jar, The 75
Litharge 38
Lithium 10
Liquid, A 53
Lixiviation 4
Loadstone 30
Lunar caustic 46
Magnesium 21
,, Carbonate .. 22
,, Chloride 21
,, Oxide 21
,, Sulphate 21
,, Tests 22
Magnesia Alba 22
Manganesium 24
Massicot 38
Metals of the Earth, The .. 18
Mercury 42
,, Chlorides 43
,, Oxides 42, 34

PAGE
Mercury Nitrates 44
,, Sulphides 43
Microcosmic Salt 11
Molecule, A 50
Molecular Weight 58
Mordant 20
Muntz-Metal 39
Nickel 31
Nitrification 5
Nomenclature of Salts 52
,, ,, Protosalts 52
,, ,, Persalts 52
,, ,, Subsalts 52
"Paste" 20
Plaster of Paris 15
Pearlashes 4
Petalite 10
Perissads 51
Platinum 48
,, Chlorides 48
,, Oxides 48
,, Tests 49
"Poling" 40
Potassium 2
,, Bicarbonate 4
,, Bisulphate 6
,, Bromide 6
,, Carbonate 4
,, Chlorate 5
,, Chloride 5
,, Hydrosulphate 6
,, Iodide 6
,, Nitrate 4
,, Oxides 3
,, Sulphate 6
,, Sulphides 6
,, Tests 7
Purple of Cassius 47
Putty Powder 33
Puddling 27
Pyrolusite 25
Quantivalence 2, 50, 60
Radicals 64
,, Acidulous 64
,, Basylous 64
,, Compound 65
,, Elementary 64
Red Hæmatite 26
Rubidium 13
Rules and Examples for the Solution of Questions on Chemical Formulæ and Percentage Composition 85
Rust 26
Silver 45
,, Bromide 46
,, Chloride 46
,, *Iodide* 46

PAGE
Silver Nitrate 45
,, Oxides 45
,, Sulphide 46
,, Tests 46
Silver Group, The 39
,, ,, General Characteristics of the 46
Silver-Glance 46
Sodium 7
,, Bicarbonate 9
,, Carbonate 8
,, Chloride 8
,, Nitrate 9
,, Sulphate 8
,, Tests 9
Solid, A 53
Spathose-iron-ore 29
Specular-iron-ore 29
Specific Weight or Gravity 54
,, ,, For Gases 54, 58
,, ,, For Liquids 55
,, ,, For Solids 56
,, ,, For Vapours 55
Spitting 45
Spodumene 10
Strontianite 16
Strontium 16
,, Oxides 16
,, Tests 16
Spongy Platinum 48
Standard Gold of England 47
Tables of Analyses for Acids 101
,, ,, for Metals 91
Tartar Emetic 85
Tin 33
,, Sulphides 34
,, Oxides 33
,, Tests 34
Tin Prepare Liquor 34
Tin-White-Cobalt 21
Type Metal 34
Varvacite 25
Vermilion 43
Volume, A 53
Welding 28
White Lead 33
Wrought Iron 26
Yellow Wash 44
Zinc 22
,, Carbonate 23
,, Chloride 23
,, Oxide 23
,, Sulphate 23
,, Sulphide 23
,, Tests 23
Zinc Group, The 21
,, ,, General Characteristics of the 24